1969

Section X

19960611 163

ASME BOILER AND PRESSURE VESSEL CODE

FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

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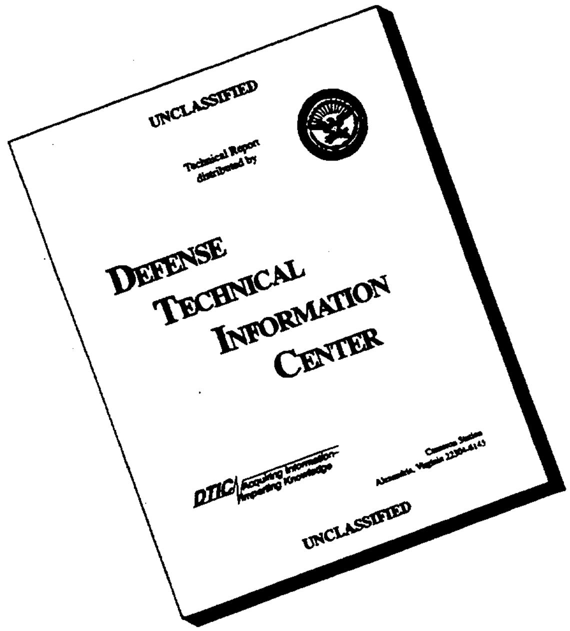

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Winter 1969 Addenda

ASME BOILER AND PRESSURE VESSEL CODE

SECTION X

FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

1969 Edition

Date of Issue, December 15, 1969

D-140(b)

Add a second sentence to read:

To be considered fire-retardant, such resin-glass laminate should be judged self-extinguishing, using the criteria of ASTM Specification D 635 and, in addition, should have a maximum burning rate of 1 inch per minute, as determined by the procedures of ASTM Specification D 757.

D-160

In line 3 insert full-scale *before* prototype *and, after* vessels *but before the succeeding comma, insert:* (see Par. G-321(f)(3)).

T-400

Add a second sentence to read:

The hydrostatic tests shall not be run until other tests stipulated in this Article have been conducted.

Form RP-1

Revise note for item 13 to read:

(Brief description of purpose of the vessel, such as air tank, water tank, L. P. G. Storage, etc. *If description of the purpose of the vessel does not clearly indicate the contents of the vessel, state what the contents are to be.* Describe any unusual features of design or construction not covered by items 3 to 12 inclusive.)

Printed in U.S.A.

ADDENDA TO 1968 ASME BOILER AND PRESSURE VESSEL CODE

Issued up to December 31, 1969

	Issued	Price
To Section I, Power Boilers		
Summer 1968	June 30, 1968	$1.00
Winter 1968	Dec. 31, 1968	$1.00
Summer 1969	June 30, 1969	$1.00
Winter 1969	Dec. 31, 1969	$2.00
To Section II, Material Specifications		
Part A – Ferrous		
Summer 1968	None Issued	–
Winter 1968	Dec. 31, 1968	$2.00
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Winter 1969	Dec. 31, 1969	$1.00
Part B – Nonferrous		
Summer 1968	None Issued	–
Winter 1968	Dec. 31, 1968	$1.00
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Winter 1969	Dec. 31, 1969	$1.00
To Section III, Nuclear Vessels		
Summer 1968	June 30, 1968	$1.00
Winter 1968	Dec. 31, 1968	$1.00
Summer 1969	June 30, 1969	$2.00
Winter 1969	Dec. 31, 1969	$2.00
To Section IV, Heating Boilers		
Summer 1968	June 30, 1968	$1.00
Winter 1968	Dec. 31, 1968	$1.00
Summer 1969	June 30, 1969	$1.00
Winter 1969	Dec. 31, 1969	$1.00

	Issued	Price
To Section VII, Care of Power Boilers		
Summer 1968	None Issued	–
Winter 1968	None Issued	–
Summer 1969	None Issued	–
Winter 1969	None Issued	–
To Section VIII, Pressure Vessels, Division 1		
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Summer 1969	June 30, 1969	$2.00
Winter 1969	Dec. 31, 1969	$2.00
Division 2		
Winter 1968	Nov. 15, 1968	$1.00
Summer 1969	June 30, 1969	$2.00
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To Section IX, Welding Qualifications		
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Winter 1969	Dec. 31, 1969	$1.00
To Section X, Fiberglass Reinforced Plastic Pressure Vessels (1969)		
Winter 1969	Dec. 31, 1969	$1.00

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FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

1969 EDITION

December 15, 1969

ASME BOILER AND PRESSURE VESSEL COMMITTEE
SUBCOMMITTEE ON REINFORCED PLASTIC PRESSURE VESSELS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
UNITED ENGINEERING CENTER
345 EAST FORTY-SEVENTH STREET, NEW YORK, N.Y. 10017

1969 ASME Boiler and Pressure Vessel Code

Section	Title
I	POWER BOILERS
II	MATERIAL SPECIFICATIONS Part A – Ferrous Part B – Nonferrous
III	NUCLEAR VESSELS
IV	LOW-PRESSURE HEATING BOILERS
VII	RECOMMENDED RULES FOR CARE OF POWER BOILERS
VIII	PRESSURE VESSELS – DIVISION 1 ALTERNATIVE RULES FOR PRESSURE VESSELS – DIVISION 2
IX	WELDING QUALIFICATIONS
X	FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

Case Interpretations

The Boiler and Pressure Vessel Committee meets regularly to consider requests for interpretations of the Code and to consider rulings for conditions encountered requiring special provisions. Those which have been adopted are published in a case interpretation booklet.

Interpretation and Addenda Service

Colored Sheet Addenda, which include additions to and revisions of all existing sections of the Code, and subsequent case interpretations in white loose leaf sheets may be obtained from the ASME Publication Sales Department at an annual subscription price.

Addenda Color Legend

Blue	Winter 1969
Orange	Summer 1970
Buff	Winter 1970

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Foreword

The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee.

The Committee's function is to establish rules of safety governing the design, the fabrication, and the inspection during construction of boilers and pressure vessels, and to interpret these rules when questions arise regarding their intent. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels.

The Boiler and Pressure Vessel Committee deals with the care and inspection of boilers and pressure vessels in service only to the extent of providing suggested rules of good practice as an aid to owners and their inspectors.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Boiler and Pressure Vessel Committee meets regularly to consider requests for interpretations and revisions of the rules. Inquiries must be in writing and must give full particulars in order to receive consideration. Requests for interpretations which are of a routine nature may be executed by the Secretary of the Boiler and Pressure Vessel Committee without reference to a subcommittee. All other requests are first referred to the proper subcommittee for consideration and for recommendation of action by the Main Committee. The action of the Main Committee becomes effective only after confirmation by letter ballot of the Committee and approval by the Council of the Society.

Interpretations of general interest are published in *Mechanical Engineering* as Code Cases, and inquirers are advised of the action taken. Code revisions approved by the Committee are published in *Mechanical Engineering* as proposed addenda to the Code to invite comments from all interested persons. After final approval by the Committee and adoption by the ASME Council, they are printed in the addenda supplements to the Code.

Code Cases (interpretations) may be used in the construction of vessels to be stamped with the ASME Code symbol beginning with the date of their approval by the ASME Council.

After Code revisions are approved by council they may be used beginning with the date of issuance shown on the addenda. Revisions become mandatory as minimum requirements six months after such date of issuance, except for boilers or pressure vessels contracted for prior to the end of the six month period.

Manufacturers and users of pressure vessels are cautioned against making use of revisions and Cases that are less restrictive than former requirements without having assurance that they have been accepted by the proper authorities in the jurisdiction where the vessel is to be installed.

Each state and municipality in the United States and each province in the Dominion of Canada that adopts or accepts one or more Sections of the Boiler and Pressure Vessel Code is invited to appoint a representative to act on the Conference Committee to the Boiler and Pressure Vessel Committee. Since the members of the Conference Committee are in active contact with the administration and enforcement of the rules, the requirements for inspection in this Code correspond with those in effect in their respective jurisdictions. The required qualifications for an authorized inspector under these rules may be obtained from the administrative authority of any state, municipality, or province which has adopted these rules.

The Boiler and Pressure Vessel Committee in the formulation of its rules and in the establishment of maximum design and operating pressures considers materials, construction, method of fabrication, inspection, and safety devices.

Permission may be granted to regulatory bodies and organizations publishing safety standards to use a complete Section of the Code by reference. If usage of a Section, such as Section VIII, involves exceptions, omissions, or changes in provisions, the intent of the Code might not be attained.

Where a state or other regulatory body, in the printing of any Section of the ASME Boiler and Pressure Vessel Code, makes additions or omissions, it is recommended that such changes be clearly indicated.

The National Board of Boiler and Pressure Vessel Inspectors is composed of chief inspectors of states and municipalities in the United States and of provinces in the Dominion of Canada that have adopted the Boiler and Pressure Vessel Code. This Board, since its organization in 1919, has functioned to uniformly administer and enforce the rules of the Boiler and Pressure Vessel Code. The cooperation of that organization with the Boiler and Pressure Vessel Committee has been extremely helpful. Its function is clearly recognized and, as a result, inquiries received which bear on the administration or application of the rules are referred directly to the National Board. Such handling of this type of inquiry not only simplifies the work of the Boiler and Pressure Vessel Committee, but action on the problem for the inquirer is thereby expedited. Where an inquiry is not clearly an interpretation of the rules, nor a problem of application or administration, it may be considered both by the Boiler and Pressure Vessel Committee and the National Board.

It should be pointed out that the state or municipality where the Boiler and Pressure Vessel Code has been made effective has definite jurisdiction over any particular installation. Inquiries dealing with problems of local character should be directed to the proper authority of such state or municipality. Such authority may, if there is any question or doubt as to the proper interpretation, refer the question to the Boiler and Pressure Vessel Committee.

The specifications for materials given in Section II of the Code are identical with or similar to those of the American Society for Testing Materials as indicated, except in those cases where that organization has no corresponding specification.

Statement of Policy on Use of Code Symbols in Advertising

The American Society of Mechanical Engineers established a series of symbols, for the marking of boilers, pressure vessels, and certain appurtenances which have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to maintain the standing of the Code Symbols for the benefit of the users, the enforcement jurisdictions, and the holders of the symbols who comply with all requirements. Based on that objective the following policy has been established on the usage in advertising of facsimiles of the symbols and reference to Code construction.

The American Society of Mechanical Engineers does not "approve," "certify," "rate" or "endorse" any product or construction and there shall be no statements or implications which might so indicate. A manufacturer holding a Code Symbol and a Certificate of Authorization may state in advertising literature that its products "are built in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code."

The ASME Symbol shall be used only for stamping and name plates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of a Code Symbol who may also use the facsimile in advertising to show that clearly specified products will carry the symbol. General usage is permitted only when *all* of a manufacturer's products are constructed under the Rules.

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SECTION X

FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

TABLE OF CONTENTS

APPENDICES

ASME BOILER AND PRESSURE VESSEL CODE
SECTION X
FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

This 1969 Edition of Section X,
Fiberglass-Reinforced Plastic Pressure Vessels,
was approved by the Council of The American Society of Mechanical Engineers on
January 15, 1969.

INTRODUCTION

1 The current philosophies of the present Section I (Power Boilers), Section III (Nuclear Vessels), Section VI (Heating Boilers) and Section VIII (Pressure Vessels) as regards design, fabrication and inspection are generally based on the use of metallic materials. These basic metallic materials are produced to designated physical, chemical and metallurgical specifications usually by a concern other than the vessel manufacturer. The basic material is formed into shapes or parts that are joined by mechanical or welding (including brazing) processes. The design rules are for the most part based on specific stress values assigned to the basic material. General rules are provided for determining the suitability of and for controlling of the joining processes. Inspection and testing requirements are based on visual inspection during and after fabrication, nondestructive testing, and hydrostatic testing.

2 In developing rules for reinforced plastic pressure vessels it was necessary for the Committee to deviate considerably from the aforementioned philosophies and it is the purpose of this introduction to describe in a general way the criteria that were used in preparing Section X, Fiberglass-Reinforced Plastic Pressure Vessels.

MATERIALS

3 It is not possible to fabricate a reinforced plastic pressure vessel of a single basic material for which there is an ASTM specification. The vessel parts are made up of various basic materials, such as glass and resin, which are joined in the presence of a catalyst to create a composite material that is formed into a vessel or vessel part by a specified process. General specifications for the basic materials (glass and resin) are stated, as are minimum physical properties for the composite material (laminate) produced. Metallic materials, when used in conjunction with reinforced glass laminates, are required to meet existing applicable ASME Boiler and Pressure Vessel Code specifications.

DESIGN

General

4 Adequacy of specific designs is based on qualification tests since the design criteria and formulas used in Section VIII are not necessarily applicable. This is because of the general characteristics of the composite material (laminate) and the methods employed in fabrication. The qualification tests require that the minimum burst pressure of the vessels be six times the design pressure. Until more experience is obtained, the maximum design pressure is being limited to 150 psi for bag-molded and centrifugally cast vessels and 1500 psi for filament-wound vessels.

Low Modulus Characteristics

5 Fiberglass-reinforced plastic pressure vessels may have a modulus of elasticity as low as 1.0×10^6 compared with that of ferrous vessels which may be of the order of 30×10^6. This low modulus characteristic requires careful consideration of vessel profile in order to minimize bending, and avoid buckling. Spherical heads or elliptical heads with an ellipse ratio not greater than 1.5 to 1 are suggested.

Fatigue

6 Like metallic materials, the composite material (laminate) of fiberglass-reinforced plastic vessels, when stressed at sufficiently low levels, exhibits good fatigue life. However, its low modulus of elasticity indicates a higher strain per unit of stress than any Code-used metals. Moreover, it has little ability to deform plastically. In spite of these characteristics, data and experience, accumulated over a period of 15 years, demonstrate that adequately designed vessels, when stressed at 25 percent of the tensile strength of the laminate, will have a fatigue life of about 250,000 cycles. Section X, therefore, requires that a design be qualified by pressure cycling it 100,000 times over a pressure range of atmospheric to the design pressure which will develop a hoop stress of $16\frac{2}{3}$ percent of the tensile strength; after this the test vessel must withstand a hydrostatic burst test not less than six times the design pressure.

Creep, Stress-Rupture and Temperature Effects

7 Fiberglass-reinforced plastic composite material (laminate) is not subject to creep and failure due to low stress-to-rupture characteristics as are some other materials. The material does, however, lose ultimate strength as the temperature is increased and gains strength as the temperature is lowered below the ambient. Its low thermal conductivity and ablative properties are other factors significantly affecting the behavior of this material in the event of fire or other high temperature environment. Until more experience is obtained, the maximum design, operating and test temperatures are set at 150 F.

Fabrication

8 There are many processes being used in the production of fiberglass-reinforced composite materials (laminates). However, Section X has been deliberately limited to three processes, namely, filament-winding, bag-molding and centrifugal-casting. These processes have been chosen because they are adaptable to other requirements of Section X, such as basic materials, production process control and quality control.

9 The fabrication of more than one vessel to comply with the rules of this Section is necessary because of the qualification testing requirements. Once a specific design has been qualified, then the quality of subsequent vessels of the same design is to be assured by carefully controlled production procedures and rigid quality control programs.

INSPECTION

10 The general philosophy of Division 1 of Section VIII as regards inspection during fabrication is continued in Section X. Some familiarity with the production processes and the nature of vessel imperfections is required. Reliance is placed upon careful auditing of the manufacturer's quality control program and close visual in-

spection of completed vessels.

11 Section X requires that all vessels be fabricated without the use of pigment or fillers so as to produce a translucent laminate. This will permit using a suitable light source to determine that the vessel is free of harmful imperfections and that there is no gross variation in thickness. Thickness measurements may be made by ultrasonic devices.

LINERS

12 Liners may be used in these vessels as a barrier between the laminate and the vessel contents for purposes of corrosion resistance, to prevent leakage of filament-wound vessels or contamination of the vessel contents. A translucent liner is preferable but an opaque liner may be used if the laminate is sufficiently translucent.

PART G
GENERAL REQUIREMENTS

ARTICLE G-1
SCOPE AND JURISDICTION

G-100 SCOPE

(*a*) Section X establishes the minimum requirements for the construction of fiberglass-reinforced thermosetting plastic pressure vessels for general service, sets limitations on the permissible service conditions, and defines the types of vessels to which its rules are not applicable.

(*b*) To insure that vessels constructed according to these rules will be capable of safely withstanding the operating conditions specified by the User, this Section:

(*1*) Gives minimum requirements for the materials of construction;

(*2*) Suggests nonmandatory design procedures;

(*3*) Defines the general methods of fabrication which may be used;

(*4*) Limits the types of end closures, connections and attachments which may be employed and the means used to join them to the vessels;

(*5*) Stipulates the procedures to be used in proving that prototype vessels can safely withstand specified operating conditions;

(*6*) Establishes rules under which fabricating procedures, used for manufacturing both prototype and production vessels, are qualified and defines what deviations from such procedures necessitate requalification;

(*7*) Sets forth in-process test requirements to insure that no essential variation in qualified fabrication procedures has occurred;

(*8*) Establishes rules for acceptance testing, inspection and reporting;

(*9*) Gives requirements for stamping and marking.

G-110 APPLICATION LIMITATIONS[1]

G-111 Design Pressure

The internal design pressure of vessels constructed under Section X shall not exceed 150 psi for bag-molded and centrifugally cast vessels nor 1500 psi for vessels which are completely filament-wound with continuous filaments.

G-112 Design Temperature

The design temperature of vessels constructed under Section X shall not exceed 150 F nor be less than minus 65 F (see Par. D-112)

[1] The limitations of pressure and temperature for this initial edition of Section X are well within the range for which design, construction and service experience with fiberglass-reinforced plastic pressure vessels has been obtained. As experience is gained, consideration will be given to modifying these limitations.

G-113 Lethal Fluids[1]

Vessels constructed under Section X shall not be used to store, handle or process lethal fluids.

G-120 JURISDICTION OF SECTION X

The jurisdiction of this Section is intended to include only the vessel and integral communicating chambers and to terminate at the points defined in the following subparagraphs (a) and (b).

(*a*) Where external piping is connected to the vessel, the jurisdiction shall terminate at:

(*1*) The face of the first flange in bolted flange connections;

(*2*) The first threaded joint in that type connection;

(*3*) The first circumferential adhesive-bonded joint in that type connection;

(*4*) The first circumferential welded joint in that type connection.

(*b*) Where lugs, skirts or other supporting structures are joined directly to a vessel, the jurisdiction shall terminate at the first joint or connection beyond the vessel but shall include the attachment of such supporting structures to the vessel.

G-121 Classes of Vessels Outside Jurisdiction of this Section

The following classes of fiberglass-reinforced plastic pressure vessels are not under the jurisdiction of this Section:

(*a*) Vessels subject to Federal control;

(*b*) Vessels with a nominal water-containing capacity of 120 gallons or less for containing water under pressure, including those containing air, the compression of which serves only as a cushion;

(*c*) A hot water supply storage tank heated by stream or any other indirect means when neither of the following limitations is exceeded:

(*1*) A heat input of 200,000 Btu per hour;

(*2*) A nominal water-containing capacity of 120 gallons.

(*d*) Vessels having an internal or external operating pressure not exceeding 15 psig with no limitation on size;

(*e*) Vessels having an inside diameter not exceeding 6 inches.

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[1] By "lethal substances" are meant poisonous gases or liquids of such a nature that a very small amount of the gas or of the vapor of the liquid mixed or unmixed with air is dangerous to life when inhaled. For purposes of the Code this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel. Some such substances are hydrocyanic acid, carbonyl chloride, cyanogen, mustard gas, and xylyl bromide. For design purposes under this Code, chlorine, ammonia, natural or manufactured gas, any liquefied petroleum gas (such as propane, butane, butadiene), and vapors of any other petroleum products are not classified as lethal substances.

ARTICLE G-2
ORGANIZATION

G-200 ORGANIZATION OF THIS SECTION

G-201 Parts

These rules are divided into nine major parts:

(*a*) Part G, applying to all methods and materials of construction;

(*b*) Part M, setting forth rules governing materials;

(*c*) Part D, providing design requirements;

(*d*) Part F, giving rules for specific methods of fabrication;

(*e*) Part Q, containing rules for qualifying the procedures used in carrying out the methods of fabrication;

(*f*) Part R, giving rules for pressure-relief devices;

(*g*) Part T, establishing methods for qualifying designs and procedure specifications, for quality control testing and for production testing;

(*h*) Part I, giving rules for inspection;

(*i*) Part S, setting forth stamping and marking requirements.

G-202 Articles, Paragraphs and Subparagraphs

(*a*) The Parts of this Section are divided into Articles. Each Article is given a number and a title, e.g., Part G, Article G-3, Responsibilities and Duties.

(*b*) Articles are divided into paragraphs which are a three-, or occasionally a four-digit number, the first of which corresponds to the Article number, thus under Article G-3, Paragraph G-310, User's Responsibilities.

(*c*) Paragraphs are divided into subparagraphs. Major subdivisions of paragraphs are designated by suffixing to the above mentioned three- or four-digit numbers a decimal point followed by a digit or digits. Where necessary, divisions of subparagraphs are indicated by letters and further subdivisions by numbers in parentheses.

(*d*) Minor subdivisions of paragraphs are indicated by letters instead of decimals followed by digits.

(*e*) A reference in one of the paragraphs of this Section to another such paragraph includes all of the applicable rules in the referenced paragraph and its subdivisions, unless otherwise stipulated.

ARTICLE G-3
RESPONSIBILITIES AND DUTIES

G-300 RESPONSIBILITIES AND DUTIES

The various parties involved in the work of producing vessels under this Section of the Code have definite responsibilities or duties in meeting Code requirements. The responsibilities and duties set forth hereinafter relate only to Code compliance and are not to be construed as involving contractual relationships or legal liabilities.

G-310 USER RESPONSIBILITIES

The User, or an agent[1] acting in his behalf, requiring that a vessel be designed, constructed, tested and certified to be a Code vessel complying with these rules, shall provide or cause to be provided for such a vessel information as to operating conditions, including contents, in such detail as will provide the basis for design, materials, construction and inspection in accordance with these rules. This information shall be designated hereinafter as the Design Specification.

G-320 MANUFACTURER'S RESPONSIBILITIES

The structural integrity of a vessel or part thereof, including the ability to contain pressure, and its conformance with the Design Report (see Par. G-321) are the responsibility of the Manufacturer of the pressure part. The Manufacturer, completing any vessel to be marked with the Code RP symbol, has the responsibility of complying with all the requirements of this Section and, through proper certification, of assuring that any work done by others also complies with all the requirements of this Section.

G-321 Manufacturer's Design Report

(*a*) As a part of his responsibility for the structural integrity of the vessel and its ability to contain pressure, the Manufacturer or the design agent responsible to him shall make design calculations of the type suggested in Appendix 1. Such design calculations shall constitute only a tentative determination that the design, as shown on the drawings, complies with the requirements of this Section for the design conditions set forth in the Design Specification.

(*b*) It shall be the Manufacturer's responsibility to prove that a vessel so designed can safely withstand the service conditions set forth in the Design Specification. The proof shall consist of subjecting one or more prototype vessels to destructive tests, as required by the rules of this Section (see Par. T-224) and using the procedures established therein. A report of such tests, designated Test Report, shall be prepared and certified by the Manufacturer and the Inspector.

(*c*) It shall be the Manufacturer's responsibility to prepare and qualify a Procedure Specification. This shall specify the materials and the procedure employed to fabricate them into the prototype vessel or vessels used to prove the ability of such vessel or vessels to withstand safely the

[1]Wherever the word "User" appears in this document, it shall be considered to include an agent acting in his behalf.

service conditions set forth in the Design Specification. The Procedure Specification shall provide, as a minimum, all the information concerning the fabricating procedure, required by the recommended forms for qualifying the design and the Procedure Specification, Forms Q-106, Q-107 and Q-115, whichever is applicable.

(*d*) It shall be the Manufacturer's responsibility to conduct Quality Control Tests in accordance with the requirements of Article T-3 and to record the results thereof to insure that all other vessels, fabricated in accordance with the qualified Procedure Specification, are the equivalent of the prototype vessel or vessels tested to prove that the design and the procedure used in fabricating them will produce vessels capable of safely withstanding the service conditions set forth in the Design Specification.

(*e*) It shall be the Manufacturer's responsibility to conduct Production Tests as stipulated in Article T-4 and to record the results as assurance that such vessels are in compliance with this Section X and are acceptable for marking with the Code symbol.

(*f*) It shall be the responsibility of the Manufacturer to prepare a Manufacturer's Design Report consisting of the documents required by the preceding subparagraphs, namely:

(*1*) The Design Specification setting forth the service conditions;

(*2*) The Design Drawings and Calculations;

(*3*) The Test Report in which is given empirical proof that the prototype vessel(s) conforming to the Design Drawings can safely withstand the specified service and test conditions;

(*4*) The Procedure Specification, giving the fabrication procedures used to produce both the prototype vessel(s) and any to be certified as conforming to these rules, together with the form on which the qualification of the procedure is recorded;

(*5*) The records of the Quality Control Tests, giving the results of the in-process tests used to insure that no essential variations from the requirements of the Procedure Specification are occurring.

The foregoing five documents shall constitute the Manufacturer's Design Report. It shall be certified by the Manufacturer and shall be made available to the authorized Inspector. It shall be kept on file at the Manufacturer's place of business or at a safe depository for at least five years. When fabrication of specific, mass-produced vessels over an indefinite period of time is involved, the Manufacturer's Design Report on each specific design shall be kept on file for at least five years after production of such vessels has ceased. A copy of the Design Drawings and Design Calculations shall be furnished to the User or his agent, and when requested, a copy of the Test Report shall also be furnished.

G-322 Certification of Compliance

It is the responsibility of the Manufacturer to certify to compliance with the rules of this Division by execution of the appropriate Manufacturer's Data Report (see Forms RP-1 and RP-2)

G-330 INSPECTOR'S DUTIES

(*a*) It is the duty of the Inspector to make all the inspections required by the rules of this Section and, in addition, such other inspections and investigations as are necessary in his judgment to verify that:

(*1*) The Manufacturer's Design Report is on file and has been properly executed;

(*2*) The design conforms to the Design Drawings;

(*3*) The material and fabrication procedures being used conform to the requirements of the Procedure Specification;

(*4*) The tests stipulated in Article T-3 substantiate that the Procedure Specification is being followed.

(*b*) It is not the duty of the Inspector to verify the accuracy or completeness of the Design Calculations but he shall certify the recommended forms (or their equivalent) for qualifying the design of the vessel, the Procedure Specification under which it is produced and the design and the Procedure Specification for adhesive-bonding, if used (see Forms Q-106, Q-107 and Q-115).

(*c*) The Inspector shall certify on the Manufacturers' Data Report that all of the requirements of this Section have been met.

ARTICLE G-4
NOMENCLATURE AND CLASSIFICATION

G-400 NOMENCLATURE[1] AND CLASSIFICATION

For purposes of this Section fiberglass-reinforced plastic pressure vessels are divided into three classes according to their method of production.

G-401 Bag-Molding

In this process a pressurized bag is used to compress pre-rolled fiberglass cylinders and head preforms, which are impregnated with a suitable resin system, against an outer heated mold. This process produces vessels with integral heads and cylindrical bodies.

G-402 Centrifugal-Casting

In this process the cylindrical sections of the vessel are formed from chopped fiberglass strands and a resin system in a mandrel, which is spun to produce a suitable laminate, and heated to effect a cure of the resin system. The heads are made in separate molds by bag molding or by the matched-die-molding process.[2] The heads are cured, then the end walls may be machined to fit into, or over, matching surfaces on the cylinders. The heads and cylinders are joined by adhesive resins.

G-403 Filament-Winding

In this process continuous filaments of glass, with a suitable resin system applied, are wound in a systematic manner under controlled tension and cured on a mandrel or other supporting structure. Where the full strength of structure inherent in this process is required, heads are made integral and the filaments on the heads are wound continuous with the cylindrical portion. Fittings and attachments with provision for opening reinforcement are normally integrally wrapped into the filament-wound structure. Heads may be attached with suitable adhesive resins, the same as with centrifugally cast cylinders.

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[1] A glossary of terms used in fiberglass-reinforced plastic pressure vessel fabrication is given in Appendix 4.

[2] In the matched-die process, parts are made by applying fiberglass mats to a die, adding a resin system, then forcing a matching die into overlapping edge relation and applying heat to both dies to effect a cure.

PART M
MATERIAL REQUIREMENTS

ARTICLE M-1
GENERAL REQUIREMENTS

M-100 LAMINATE MATERIALS

Fiberglass-reinforced plastic materials subject to pressure stress shall hereinafter be designated as laminates.

(*a*) Laminates, as herein considered, are composite structures consisting of either random short length glass filaments, for either the bag-molding or centrifugal-casting process, or of continuous glass filaments for the filament-wound process, embedded in a resin matrix.

(*b*) The material manufacturer's recommendations for storage conditions and shelf life for all laminate materials shall be followed unless quality control tests demonstrate their suitability for use.

(*c*) The vessel manufacturer shall keep on file the published specifications for all laminate materials, used in each vessel fabrication, and the material manufacturer's certification that each shipment conforms to said specification.

M-110 GLASS FIBER SYSTEM

M-110.1 Glass Composition The glass fibers used in any of the fabrication processes covered by this Section shall be Type E glass having the following composition:

Silicon Dioxide	52–56 percent
Calcium Oxide	16–25 percent
Aluminum Oxide	12–16 percent
Boron Oxide	8–13 percent
Sodium and Potassium Oxide	0–1 percent
Magnesium Oxide	0–6 percent

M-110.2 Glass Fiber Surface Treatment

(*a*) The glass fiber surface shall be treated with sizing material to provide:

(*1*) Compatibility with the resin system used in the laminate matrix;

(*2*) Processibility in the fabrication method used for the manufacture of the vessel.

(*b*) This treatment of the glass fibers shall be done when the filaments are collected into a bundle or strand at the place of manufacture of the fibers.

M-120 RESIN SYSTEM

The resin system shall consist of an epoxy or polyester resin plus a curing agent. No filler, pigment or dye which will interfere with translucent visual inspection of the laminate of the completed vessel shall be used.

M-120.1 Resin Specification The resin materials, used in construction of vessels, shall be identical with those employed when qualifying the fabrication procedure. Each such resin shall be identified by the name of its manufacturer and the trade name or number that manufacturer gives it.

(*a*) For identification purposes each shipment of polyester type resin received shall be tested for the following properties:

Liquid Form

Color	APHA or equivalent scale
Viscosity, cps at 25 C	Max.-min. limits (ASTM D-1638) Brookfield
Specific Gravity at 25 C	Max.-min. limits (ASTM D-1475)
Acid Number, max.	(mg KOH/gram resin)
Monometer, type and content	max.-min. limits
SPI Gel Test	
Gel Time, minutes	max.-min.
Cure Time, minutes	max.-min.
Peak Exotherm Temperature	max.-min.

Properties of Clear Polyester Resin Castings

Note: Castings shall be ⅛ inch thick, cured 3 hours at 180 F with 1.0 PHR of benzoyl peroxide and shall be tested at 25 C.

Specific Gravity	max.-min.
Barcol Hardness	ASTM D-2583-67
Flexural Strength	ASTM D-790
Flexural Modulus	ASTM D-790
Heat Distortion Point	ASTM D-648

The properties of the polyester resins, thus determined, shall be within the limits of the resin manufacturer's specification. A record of these determinations and the properties given in the resin manufacturer's specification shall be provided for review by the Inspector.

(*b*) Each shipment of liquid epoxy type resin shall either conform to ASTM Specification D-1763 for bisphenol A, epichlorohydrin epoxy resins or, for other types of epoxy resins, liquid or solid, the following characteristics shall be determined by test for identification purposes:

Liquid Viscosity, cps at 25 C	max.-min. limits (ASTM D-1638) Brookfield
Solid Melting Point	max.-min. limits (ASTM E-28)
Epoxide Equivalent	max.-min. limits (ASTM D-1652)
Specific Gravity	max.-min. limits (ASTM D-1475)
Color, max.	(ASTM D-1544)
Hydrolyzable Chlorine, max. percent by wt.	(ASTM D-1726)

Properties of Clear Epoxy Resin Castings

Note: Castings shall be ⅛ inch thick, cured with a suitable hardener and an appropriate time-temperature cycle and shall be tested at 25 C.

Barcol Hardness	ASTM D-2583-67
Flexural Strength	max.-min. (ASTM D-790)
Flexural Modulus	max.-min. (ASTM D-790)
Heat Distortion Point	max.-min. (ASTM D-648)

M-120.2 Curing Agents The curing agents, used in construction of vessels, shall be identical with those employed when qualifying the fabrication procedure. Each such curing agent shall be identified by the name of its manufacturer and the trade name or number that manufacturer gives it.

(*a*) *For polyester resins* The type, form, concentration used in resin and method of incorporation shall be the same as those used in the initial, successful qualification test. The combination of specified polyester and specified curing agent must be capable of meeting or exceeding strength values of clear resin castings given in Par. M-120.1(a).

(*b*) *For epoxy resins* A variety of hardeners may be used to cure epoxy resins (BP_3-amine catalysts, polyamines, polyamides, dibasic acid anhydrides, phenolic resins, etc.), and sometimes more than one hardener will be used in the same resin system. If the specific hardener is not a simple compound, the hardener, or hardeners,

shall be determined by test to have the following characteristics:

Viscosity (if liquid) cps at 25 C	max.-min. limits (ASTM D-1638) Brookfield
Specific Gravity	max.-min. limits (ASTM D-1475)
Amine Value	max.-min. limits (if appropriate)
Parts Hardener /100 Parts Resin (WPE 190)	max.-min. limits
Pot Life, 100 g mass, 25 C, minutes	max.-min. limits

In addition, the resin-hardener system used shall be capable of meeting or exceeding strength values of clear resin castings given in Par. M-120.1(b) with the cure cycle specified.

M-130 MINIMUM REQUIRED MECHANICAL PROPERTIES

M-130.1 Tensile Strength The laminates used in vessels conforming to these rules shall have minimum tensile strengths, as determined by hydrostatic bursting pressure tests (see Par. T-224), as follows:

Tensile Strength, Psi

Bag-Molding Process	25000
Centrifugal-Casting Process	15000
Filament-Winding Process	45000 (longitudinal) 90000 (circumferential)

M-130.2 Interlaminate Shear Strength The laminates used in filament-wound vessels shall have minimum interlaminar shear strengths of 5000 psi for polyester resins and 7000 psi for epoxy resins determined in accordance with ASTM Specification D-2344-65T at the time of qualifying the procedure.

M-140 USE OF TWO OR MORE MATERIAL SPECIFICATIONS OR PROCESSES IN FABRICATING A VESSEL

Materials covered by different specifications or processes may be used in fabricating a pressure vessel, provided each material conforms to its respective specification.

ARTICLE M-2
MISCELLANEOUS PRESSURE PARTS

M-200 GENERAL REQUIREMENTS

Prefabricated or preformed reinforced plastic pressure vessel components, which will be subjected to pressure stresses and which are produced by parties other than the manufacturer responsible for the completed vessel, shall conform to all applicable requirements of Section X, including inspection in the shop of the manufacturer of such components and furnishing partial data reports, except as permitted in Pars. M-210, M-211 and M-212.

M-210 CAST, FORGED, ROLLED, OR DIE-FORMED STANDARD PRESSURE PARTS

(*a*) Pressure parts such as pipe fittings, valves, flanges, nozzles, welding necks, welding caps, manhole frames and covers that are wholly formed by casting, forging, rolling or die forming shall not require inspection, mill test reports or partial data reports; however, they shall be made of materials permitted under Section VIII, Division 1 of the Code or in an accepted standard (such as an American National Standard) covering the particular type of pressure part. Such parts shall be marked with the name or trademark of the manufacturer and such other markings as are required by the several standards. Such markings shall be considered as the manufacturer's certification that the product complies with the material specifications and standards indicated and is suitable for service at the rating indicated. The intent of the paragraph will have been met, if, in lieu of the detailed marking on the part itself, the parts described herein have been marked in any permanent or temporary manner that will serve to identify the part with the manufacturer's written listing of the particular items and such listings are available for examination by the Inspector.

(*b*) Parts of small size falling within this category, for which it is difficult or impossible to obtain identified material or which may be stocked and for which mill test reports or certificates cannot be economically obtained and are not customarily furnished and which do not appreciably affect the safety of the vessel, may be used for relatively unimportant parts or parts stressed to not more than 50 percent of the stress value permitted by the Code, provided they are suitable for the purpose intended and meet the approval of the Inspector (see (a) above and Par. UG-6(c) of Section VIII, Division 1). The manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions specified for the completed vessel.

M-211 Cast, Forged, Rolled or Die-Formed Nonstandard Pressure Parts

Pressure parts such as shells, heads, removable doors and pipe coils that are wholly formed by casting, forging, rolling or die forming may be supplied basically as materials. All such parts

shall be made of materials permitted under Section VIII, Division 1 and the manufacturer of the part shall furnish mill test reports or other acceptable evidence to that effect. Such parts shall be marked with the name or trademark of the manufacturer and with such other markings as will serve to identify the particular parts with accompanying material identification. The manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions specified for the completed vessel.

M-212 Welded Standard Pressure Parts for Use Other than the Shell of a Vessel

Pressure parts such as pipe fittings, nozzles, welding necks, welding caps, valves and flanges that are fabricated by one of the welding processes recognized by the Code shall not require inspection, mill test reports or partial data reports provided the following requirements are met.

(*a*) All such parts are made of materials permitted under Section VIII, Division 1 or in an accepted standard (such as an American National Standard).

(*b*) If arc or gas welded, the welding complies with Pars. UW-26 to UW-40, incl. of Section VIII, Division 1.

(*c*) Such parts shall be marked with the name or trademark of the manufacturer and with such other markings as will serve to identify the materials of which the parts are made. Such markings shall be considered as the manufacturer's certification that the product complies with *(a)*. A statement by the parts manufacturer that all welding complies with Code requirements shall be accepted as evidence that the product complies with *(b)*.

(*d*) If radiography or postweld heat treatment is required by Pars. UW-10 and UW-11 of Section VIII, Division 1, it may be performed either in the plant of the parts manufacturer or in the plant of the manufacturer of the completed vessel.

(*e*) If the radiographing is done in the plant of the parts manufacturer, the completed radiographs, properly identified with the respective parts, shall be available to the authorized Inspector. If the radiographs are examined in the plant of the parts manufacturer, partial data reports shall be executed and forwarded to the vessel manufacturer.

(*f*) If heat treatment is performed at the plant of the parts manufacturer, a statement by the manufacturer that such treatment was performed shall be accepted as evidence of compliance with applicable Code paragraphs. The manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions specified for the completed vessel.

M-220 BOLTS AND STUDS

Bolts and studs may be used for the attachment of removable parts and for bolted flanged joints. Specifications, supplementary rules, and maximum allowable stress values for acceptable bolting materials are given in Subsection C of Section VIII, Division 1.

M-221 Nuts and Washers

Nuts and washers may be made of any suitable material listed in Tables UCS-23 and UNF-23 of Section VIII, Division 1. The use of washers between metal bolt heads or nuts and fiberglass-reinforced plastic laminates is mandatory. Washers shall be made of wrought metal.

M-230 RODS AND BARS

Rod and bar stock may be used in pressure vessel construction for pressure parts such as flange rings, stiffening rings, frames for reinforced openings, stays and staybolts and similar parts. Rod and bar materials shall conform to the requirements for bars, bolting or rivets in the applicable part of Subsection C of Section VIII, Division 1.

PART D
DESIGN REQUIREMENTS

ARTICLE D-1
GENERAL

D-100 SCOPE

Section X does not provide mandatory rules by which the thicknesses of parts of vessels to be subjected to internal or external pressure must be determined. Tentative thicknesses for vessel parts may be determined by the suggested design procedures given in Appendix 1 or by other procedures at the Manufacturer's option. Regardless of how the tentative thicknesses of vessel parts are determined, the adequacy of the design of a vessel or vessels to be certified for specified service conditions shall be determined by testing one or more prototype vessels to destruction in accordance with the requirements of Article T-2; all vessels to be so certified shall be constructed in strict accordance with the procedure specification utilized in fabricating the prototype vessel or vessels (see Article Q-1).

D-101 Design Basis

(*a*) The pressure of the fluid at the top of the vessel in its specified operating position, with the laminate temperature taken at 150F, shall normally be that on which the design is based; when and where applicable, static head shall be included in establishing the design basis. The pressure at the top of the vessel is also the basis for the pressure setting of the pressure-relief devices protecting the vessel and for the design pressure to be marked on the vessel.

(*b*) The design shall take into account the maximum difference in fluid pressure which can occur under the specified conditions of operation (which may include pressure due to static head) between the inside and outside of the vessel at any point or between two chambers of a combination unit.

(*c*) The design shall take into account any combination of loadings other than pressure (see Par. D-120) which may occur, coincident with the specified operating pressure and temperature. Any additional thickness required to withstand such supplementary loadings shall be added to that required to withstand pressure loading as determined by the requirements of Article T-2.

(*d*) When liners, whether metallic or non-metallic, are employed in vessels covered by this Section, no credit shall be given to the strength of the liner in establishing the design pressure. However, the weight of the liner shall be taken into account when determining loadings other than pressure.

D-110 DEFINITIONS

The terms relating to design used throughout this Section are defined in Pars. D-111 through D-116.

D-111 Design Pressure

Design pressure is the permissible pressure at the top of the vessel and is the pressure, together with the applicable, coincident laminate temperature to be marked on the nameplate. The design pressure plus any pressure, when applicable, due to static head at any point under consideration, shall not exceed the lower of 150 psi for bag-molded and centrifugally cast vessels and 1500 psi for filament-wound vessels or $\frac{1}{6}$ of the bursting pressure determined in accordance with the rules of Article T-2.

D-112 Design Temperature[1]

The design temperature, even though a lower operating temperature is specified in the Design Specification, shall be taken as 150 F and the hydrostatic bursting pressure tests used to establish the permissible design pressure shall be conducted at that temperature (see Article T-2).

D-112.1 Minimum Permissible Temperature The minimum permissible temperature to which a vessel constructed under these rules may be subjected is minus 65 F (see Par. G-112).

D-113 Operating Pressure

The operating pressure is the pressure at the top of the vessel at which it normally operates. The operating pressure shall not exceed the design pressure and is usually kept at a suitable level below the design pressure to prevent the frequent opening of pressure-relief devices.

D-114 Bursting Pressure

The bursting pressure is that hydrostatic pressure which causes a prototype vessel to burst (either before or after it has been subjected to cyclic variations of internal pressure) as proof of the adequacy of its design and construction for the specified service conditions (see Par. D-160).

D-115 Test Pressure

The test pressure is that pressure (either hydrostatic or pneumatic) to be applied at the top of the vessel prior to its being certified as conforming to the rules of this Section (see Article T-4).

D-116 Safety Valve Setting

The pressure for which safety or safety-relief valves shall be set to open is established in Pars. R-121 and R-122.

D-120 LOADINGS

The loadings to be taken into account in designing a vessel shall include:

(*a*) Internal or external design pressure as defined in Par. D-111;

(*b*) Impact loads;

(*c*) Weight of the vessel and normal contents under operating or test conditions (this includes additional pressure due to static head of liquids);

(*d*) Superimposed loads such as other vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping;

(*e*) Snow and ice loads;

(*f*) Wind loads, and earthquake loads where required;

(*g*) Reactions of supporting lugs, rings, saddles and other types of supports (see Appendix 1).

D-121 Stress Due to Combined Loading

The geometry and wall thickness of a vessel designed under these rules shall be such that:

(*a*) The vessel shall be capable of withstanding bending and shearing stresses resulting from any expected combination of loads listed in Par. D-120 and stipulated in the Design Specification (see Par. G-310);

(*b*) The maximum direct (membrane) stress due to any combination of loadings listed in Par. D-120 that are expected to occur simultaneously during normal operation of the vessel shall not exceed $\frac{1}{6}$ of the maximum membrane stress value, as determined from the burst test, and considering any additional membrane stresses caused by other test loadings in addition to the pressure loading (see Pars. D-130 and Q-130.2).

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[1] When vessels are to be subjected to sudden cyclic changes in temperature, the expected conditions shall be stated in the Design Specification and the procedure for qualifying vessels for such service conditions shall be included in the contractual agreement between the User and the Manufacturer.

D-130 DESIGN RESTRICTIONS

(*a*) Insofar as is reasonably attainable, pressure vessels constructed under the rules of this Section shall be designed to be free of bending and shearing stresses, especially if they are to be subjected to cyclic conditions of loading. Particular care shall be used in selecting the kind of end closure, whether formed head or flat head type, and of nozzle connections for attachment of piping, etc., to avoid or minimize bending and shearing stresses likely to be imposed on the structure by these design details.

(*b*) Vessels having bending and shearing stresses inherent in their design shall be so loaded during the cyclic pressure tests of the prototype units as to create in the connections the magnitude of bending and shearing stresses expected to occur under service conditions (see Par. G-310).

D-140 DESIGN ALLOWANCES FOR DEGRADATION

Design consideration shall be given to chemical or mechanical degradation of the vessels or parts of vessels and shall be directed to:

(*a*) Selection of proper materials for service requirements;

(*b*) Where the effects of a localized fire could cause the contents of a vessel to materially add fuel to the existing fire, the use of fire-retardant resins should be considered.

(*c*) Degradation from aggressive environments[1];

(*d*) Increase of thicknesses where appropriate, such as abrasive conditions.

D-150 METHODS OF FABRICATION IN COMBINATION

A vessel may be designed and fabricated by a combination of the methods of fabrication covered by these rules.

D-151 Materials in Combination

A vessel may be designed and fabricated of any combination of materials permitted by this Section including metallic materials covered in Section VIII, Division 1, provided the applicable rules for each material are followed and the requirements for joining in Part F are met. All shells and heads, except flat heads, covers and blind flanges (see Article D-7), shall be made of laminate materials as required by Par. M-100.

NOTE: Because of different moduli of elasticity and thermal coefficients of expansion of plastic and metallic materials, caution should be exercised in design and fabrication under the provisions of this paragraph in order to avoid difficulties in service under extreme temperature conditions or with unusual restraint of parts such as may occur at points of stress concentration.

D-152 Combination Units

When a vessel unit consists of more than one independent pressure chamber, operating at the same or different pressures or temperatures, each such pressure chamber (vessel) shall be designed and fabricated to withstand the most severe conditions of pressure expected in normal service. Only the parts of the chambers which come within the scope of this Section (see Par. G-100) need be fabricated in compliance with its provisions.

D-160 PROOF OF DESIGN ADEQUACY

A design shall be considered adequate for the specified service conditions when one or more prototype vessels, after having been subjected to 100,000 cycles of pressure ranging from atmospheric to the design pressure (see Par. D-111 and Article T-2), burst at a pressure not less than six times the specified maximum design pressure. The test fluid shall have a minimum temperature of 150 F during these tests.

[1] When a vessel is to be used in locations exposed to weather, a translucent weather-resisting coating shall be added to the exterior.

ARTICLE D-2
SHELLS OF REVOLUTION UNDER INTERNAL PRESSURE

D-200 GENERAL

As indicated in Par. D-100, there are no mandatory rules or formulas in this Section in accordance with which shells of revolution under internal pressure must be designed. In Appendix 1 are given suggested procedures by which, using the minimum tensile strength values given in M-130, tentative thicknesses of such vessel parts may be determined for use in fabricating prototype vessels for qualification of the design. The designer is free to use other formulas to arrive at such tentative thicknesses.

ARTICLE D-3
SHELLS OF REVOLUTION UNDER EXTERNAL PRESSURE

D-300 GENERAL

(*a*) This Section contains no mandatory formulas in accordance with which shells of revolution under external pressure must be designed.

(*b*) Jacketed vessels are outside the scope of this Section.

(*c*) While no firm formulas are given for the design of vessels under external pressure, the following factors should be taken into consideration in establishing the prototype design:

(*1*) The low modulus of elasticity of the material;

(*2*) The anisotropic character of the material;

(*3*) The lack of uniformity in centrifugally cast vessels due to different distributions and concentrations of glass fibers attainable in centrifugal castings, some of which are not suitable for external pressure;

(*4*) The orientation of filaments in filament-wound vessels.

(*d*) While there are no mandatory formulas for design, there are mandatory rules for qualifying designs of vessels for external pressure service as set forth in Pars. D-310 and D-311.

D-310 QUALIFICATION OF VESSELS FOR EXTERNAL PRESSURE SERVICE

Vessels for external pressure service shall be qualified as required by either Par. D-311 or Par. D-312.

D-311 Vessels for Both External and Internal Pressure

Vessels designed for both external and internal pressure service shall have their designs qualified as required below.

(*a*) Prototype vessels shall be subjected to 100,000 cycles of pressure ranging from the maximum external design pressure, psig, to the maximum internal design pressure, psig, without failure. These external and internal pressure tests may be carried out in two steps (see Par. T-224).

(*b*) Prototype vessels shall then withstand an external pressure, psig, of twice the maximum external design pressure, psig, without buckling.

(*c*) Prototype vessels shall then withstand a hydrostatic bursting pressure of at least six times the maximum internal design pressure.

D-312 Vessels for External Pressure only

Vessels intended for external pressure only shall be designed for a minimum of 15 psig internal pressure and shall be qualified by subjecting their prototypes to an external pressure of twice the maximum external design pressure, psig, without buckling, and to cyclic pressure and hydrostatic bursting pressure tests based on 15 psig internal design pressure.

CAUTIONARY NOTE: It is recommended that vessels intended for internal pressure only but subject by accident to partial or full vacuum be installed in systems in which they are protected from collapse by means of a vacuum breaker. Fiberglass-reinforced plastic pressure vessels are subject to buckling due to the low modulus of elasticity or flexibility characteristics of the material. It is further recommended that vessels being shipped with all openings sealed be filled with air at or above 5 psi pressure.

ARTICLE D-4
ADHESIVE-BONDING

D-400 DESIGN OF ADHESIVE-BONDED JOINTS

(*a*) Adhesive-bonded joints shall be designed to be capable of withstanding a minimum of six times the design pressure of the vessel without leakage. The adequacy of bonded joints shall be determined in accordance with the requirements of Par. D-160.

(*b*) Parts to be joined by adhesive-bonding shall be designed so that, by tapering the mating parts or other means, the stress intensifications caused by structural discontinuities are kept to a minimum or wholly eliminated.

ARTICLE D-5
OPENINGS AND THEIR REINFORCEMENT

D-500 GENERAL

As indicated in Par. D-100, there are no mandatory rules or formulas in this Section in accordance with which it can be determined how much reinforcement is required for openings. In Article 1-4 are given suggested procedures for determining how to reinforce openings for use in fabricating prototype vessels for qualification of the design. The designer is free to use other procedures.

D-510 QUALIFICATION

(*a*) The vessel, complete with all openings and their reinforcement as designed for it, shall be qualified by cyclic pressure and hydrostatic bursting pressure tests at the design temperature and pressure in accordance with Par. T-224.

(*b*) Changes outside the scope of the Design Report in the design of openings and their reinforcement shall be considered as changes in the vessel design and the vessel shall be requalified.

ARTICLE D-6
NOZZLES AND OTHER CONNECTIONS

D-600 GENERAL

Since there are no mandatory rules or formulas in this Section for the design of nozzles and other connections, the designer is referred to Articles 1-2 and 1-4 for general guidance for prototype designs.

D-610 QUALIFICATIONS

(*a*) The vessel shall be qualified by cyclic pressure and hydrostatic bursting pressure tests at the design temperature and pressure in accordance with Par. T-224 with the nozzles and/or other connections as designed for the vessel.

(*b*) Any change in the design of nozzles and/or other connections shall be considered a change in the vessel design and the combinations shall be requalified.

ARTICLE D-7
FLAT HEADS AND BOLTED CONNECTIONS

D-700 FLAT HEADS, COVERS AND BLIND FLANGES

Flat heads, covers and blind flanges shall be made of one of the metals listed in Section VIII, Division 1 for plates, forgings or castings and their minimum thicknesses shall conform to the requirements of this Article. Some acceptable types are shown in Fig. D-700.1.

D-700.1 Nomenclature The symbols used in this Article and its figures are defined, as follows:

- C = a factor depending upon the method of attachment of head, cover or flange, dimensionless
- d = diameter of the flat portion of head, cover or flange subject to fluid pressure, in.
- D = bolt circle diameter, in.
- h_G = gasket moment arm, equal to the radial distance from the center line of the bolts to the center of the gasket groove as shown in Fig. D-700.1 (b)
- P = design pressure (see Par. D-111), psi
- S = allowable stress at 150 F per applicable table of maximum allowable stress values in Section VIII, Division 1, psi
- t = minimum required thickness of flat head, cover or flange, exclusive of corrosion allowance, in.
- W = total bolt load, pounds, given for circular heads for Formulas (3) and (4), Par. UA-49 (c), Appendix II, Section VIII, Division 1

D-701 Minimum Required Thickness

The minimum required thickness of flat, unstayed, circular heads, covers and blind flanges shall be calculated by the following formula:

$$t = d\sqrt{CP/S} \qquad (1)$$

except when the head, cover or blind flange is attached by bolts causing an edge moment (Fig. D-700.1 (b)) in which case the thickness shall be calculated by

$$t = \sqrt{CP/S + 1.9\, Wh_G/Sd^3} \qquad (2)$$

When using Formula (2), the thickness, t, shall be calculated for both initial tightening and design conditions and the greater of the two values shall be used. The gasket factors to be used in determining W shall be taken from Table UA-49.1 of Section VIII, Division 1. In order to prevent excessive bending stress being imposed on the shell and its attached flange ring, it is recommended that bolts having low yield strength be employed in making up the joint.

D-710 BOLTED FLANGED CONNECTIONS

D-711 Flanges and Flanged Fittings Conforming to ANSI B16.5 – 1961

It is recommended that the dimensional requirements of flanges used in bolted flange connections to external piping conform to ANSI B16.5–1961, Steel Pipe Flanges and Flanged Fittings.

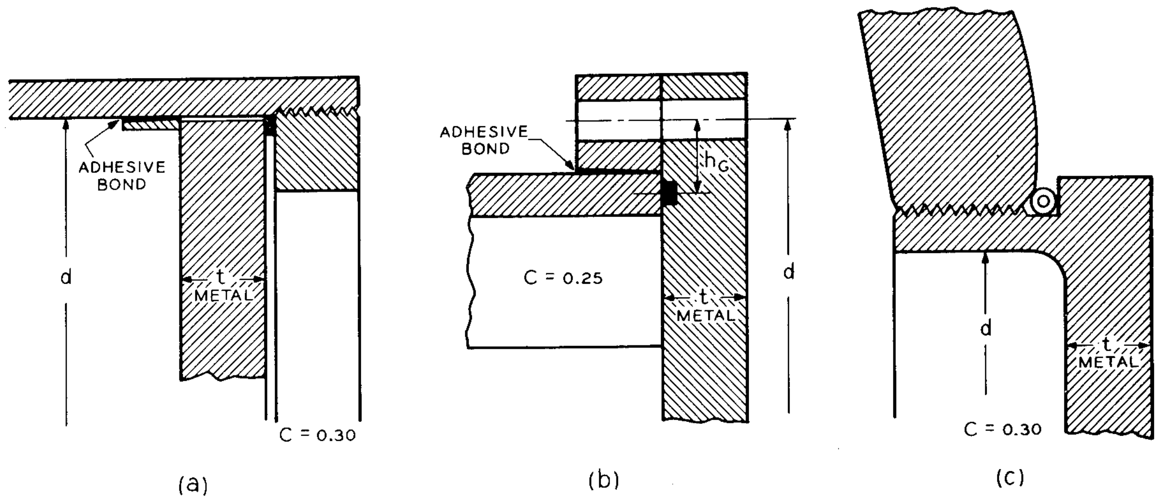

FIG. D-700.1 ACCEPTABLE TYPES OF FLAT METAL HEADS

D-712 Flanges Not Conforming to ANSI B16.5

Flanges used for joining sections of shells or for similar purposes shall be designed using full-face gaskets or other means of fixing or clamping the flange at the bolt circle to provide effective restraint against flange deflection. Such designs may be used provided they are proven adequate for the specified design conditions in accordance with Par. D-160.

D-720 OPENINGS IN FLAT HEADS, COVERS AND BLIND FLANGES

Openings in flat heads, covers and blind flanges shall conform to the requirements of Par. D-720.1 for reinforcement for all openings except that single openings in vessels do not require reinforcement other than that inherent in the construction under the following conditions:

(*a*) Welded or brazed connections attached in accordance with the applicable rules of Section VIII, Division 1, and not larger than

(*1*) 3 in. pipe size in heads $\frac{3}{8}$ in. thick or less;

(*2*) 2 in. pipe size in heads over $\frac{3}{8}$ in. thick.

(*b*) Threaded, studded or expanded connections in which the hole cut in the head is not greater than 2 in. pipe size.

D-720.1 Reinforcement Requirements

(*a*) Flat heads that have an opening with a diameter that does not exceed $\frac{1}{2}$ of the head diameter, *d*, shall have a total cross-sectional area of reinforcement not less than that given by the formula

$$A = 0.5B \times t$$

where B is the diameter of the finished opening in its corroded condition and t is as defined in Par. D-700.1.

(*b*) Flat heads that have an opening with a diameter that exceeds $\frac{1}{2}$ of the head diameter, as defined in Par. D-700.1, shall be designed in accordance with the Rules for Bolted Flange Connections in Appendix II of Section VIII, Division 1.

(*c*) As an alternative to (*b*), the thickness of flat heads may be increased to provide the necessary opening reinforcement as follows:

(*1*) In Formula (1) in Par. D-701 by using $2C$ in place of C;

(*2*) In Formula (2) in Par. D-701 by doubling the quantity under the square root sign.

D-730 WELDED OR BRAZED CONNECTIONS TO FLAT HEADS, COVERS OR BLIND FLANGES

(*a*) Connections to flat heads, covers or blind flanges attached by welding shall meet the requirements of Part UW of Section VIII, Division 1.

(*b*) Connections to flat heads, covers or blind flanges attached by brazing shall meet the requirements of Part UB of Section VIII, Division 1.

ARTICLE D-8
QUICK-ACTUATING CLOSURES

D-800 GENERAL DESIGN REQUIREMENTS

Closures other than the multibolted type designed to provide access to the contents space of a pressure vessel shall have the locking mechanism or locking device so designed that failure of any one locking element or component in the locking mechanism cannot result in the failure of all other locking elements and the release of the closure. Quick-Actuating Closures shall be so designed and installed that it may be determined by visual external observation that the holding elements are in good condition and that their locking elements, when the closure is in the closed position, are in full engagement.

D-801 Specific Design Requirements

Quick-Actuating Closures that are held in position by positive locking devices and that are fully released by partial rotation or limited movement of the closure itself or the locking mechanism and any closure that is other than manually operated shall be so designed that when the vessel is installed, the following conditions are met:

(*a*) The closure and its holding elements are fully engaged in their intended operating position before pressure can be built up in the vessel;

(*b*) Pressure tending to force the closure clear of the vessel will be released before the closure can be fully opened for access;

(*c*) In the event that compliance with *(a)* and *(b)* is not inherent in the design of the closure and its holding elements, provision shall be made so that devices to accomplish this can be added when the vessel is installed. It is recognized that it is impractical to write detailed requirements to cover the multiplicity of devices used for quick access, or to prevent negligent operation or the circumventing of safety devices. Any device or devices which will provide the safeguards broadly described in these subparagraphs (*a*), (*b*) and (*c*) will meet the intent of the Code.

D-801.1 Permissible Design Deviations for Manually Operated Closures Quick-Actuating Closures that are held in position by a locking device or mechanism that requires manual operation and are so designed that there will be leakage of the contents of the vessel prior to disengagement of the locking elements and release of closure need not satisfy Par. D-801 (*a*) (*b*) and (*c*). However, such closures shall be equipped with an audible and/or visible warning device that will serve to warn the operator, if pressure is applied to the vessel before the closure and its holding elements are fully engaged in their intended position, and, further, will serve to warn the operator, if an attempt is made to operate the locking mechanism or device before the pressure within the vessel is released.

D-802 Required Pressure-Indicating Devices

All vessels having quick actuating closures shall be provided with a pressure-indicating device visible from the operating station.

ARTICLE D-9
ATTACHMENTS AND SUPPORTS

D-900 GENERAL

As there are no mandatory rules in this Section governing the design of attachments and supports, the designer is referred to Article 1-5 for suggested procedures to be followed in establishing prototype designs.

D-910 QUALIFICATION

(*a*) The vessel complete with attachments and supports as designed for it shall be qualified by cyclic pressure and hydrostatic bursting pressure tests at the design pressure and temperature in accordance with Par. T-224.

(*b*) Any change in the design of the attachments and/or supports shall be considered a change in the vessel design and the combination shall be requalified.

ARTICLE D-10
ACCESS AND INSPECTION OPENINGS

D-1000 GENERAL REQUIREMENTS

All pressure vessels subject to internal corrosion, or having parts subject to erosion or mechanical abrasion shall be provided with suitable manhole, handhole or other inspection openings for examination and cleaning.

D-1001 Requirements for Vessel 12 in. Diameter[1] and Smaller

For vessels 12 in. or less in diameter, openings for inspection only may be omitted if there are at least two removable pipe connections not less than ¾ in. in pipe size.

D-1003 Requirements for Vessels over 12 in. but not over 16 in. Inside Diameter

Vessels over 12 in. but not over 16 in. in diameter, that are to be installed so that they must be disconnected from an assembly to permit inspection, need not be provided with openings for inspection only, if there are at least two removable pipe connections not less than 1½ in. pipe size.

D-1010 EQUIPMENT OF VESSELS REQUIRING ACCESS OR INSPECTION OPENINGS

Vessels that require access or inspection openings shall be equipped as follows[1]:

(*a*) All vessels less than 18 in. and over 12 in. in inside diameter shall have at least two handholes or two plugged, threaded inspection openings of not less than 1½ in. pipe size;

(*b*) All vessels 18 to 36 in., inclusive, in inside diameter shall have a manhole or at least two handholes or two threaded pipe plug inspection openings of not less than 2 in. pipe size;

(*c*) All vessels over 36 in. in inside diameter shall have a manhole (see Par. D-1020.1), except that those whose shape or use makes one impracticable shall have at least two handholes 4 x 6 in. or two equal openings of equivalent area;

(*d*) When handholes or pipe-plug openings are permitted for inspection openings in place of a manhole, one handhole or one pipe-plug opening shall be in each head or in the shell near each head;

(*e*) Openings with removable heads or cover plates intended for other purposes may be used in place of the required inspection openings provided they are equal at least to the size of the required inspection openings;

(*f*) A single opening with removable head or cover plate may be used in place of all the smaller inspection openings provided it is of such size and location as to afford at least an equal view of the interior.

[1] Diameters of vessels and sizes of openings are nominal.

D-1020 SIZE OF ACCESS AND INSPECTION OPENINGS

When inspection or access openings are required, they shall comply at least with the following requirements:

D-1020.1 Type and Minimum Size of Manhole An elliptical or obround manhole shall be not less than 11 x 15 in., or 10 x 16 in. A circular manhole shall be not less than 15 in., inside diameter.

D-1020.2 Minimum Size of Handholes A handhole opening shall be not less than 2 x 3 in., but should be as large as is consistent with the size of the vessel and the location of the opening.

D-1021 Design of Access and Inspection Openings in Shells and Heads

All access and inspection openings in a shell or unstayed head should be designed in accordance with the suggested procedures of Appendix 1 or their equivalent and shall be incorporated in the prototype vessel or vessels used to qualify the design in accordance with Par. D-160.

D-1022 Minimum Gasket Bearing Widths for Manhole Cover Plates

Manholes of the type in which the internal pressure forces the cover plate against a flat gasket shall have a minimum gasket bearing width of $^{11}/_{16}$ in.

D-1025 Threaded Openings

D-1025.1 Materials for Threaded Plugs and Caps

(*a*) When a threaded opening is to be used for inspection or cleaning purposes, the closing plug shall be designed with due consideration of the relationships between the moduli of elasticity of the materials of the vessel and the plug and between the thermal coefficients of expansion of those materials.

(*b*) The vessel, with the threaded opening and closure in place, must be qualified by cyclic pressure and hydrostatic bursting pressure tests in accordance with Par. T-224.

(*c*) Any change in the design of opening in the direction of a larger opening is to be considered a change in the design of the vessel and the vessel with new opening or openings must be requalified.

D-1025.2 Permissible Types of Threads The thread shall be a standard taper pipe thread except that a straight thread of equal strength may be used, if other sealing means to prevent leakage are provided.

PART F
FABRICATION REQUIREMENTS

ARTICLE F-1
GENERAL REQUIREMENTS

F-100 SCOPE

This Part provides rules governing the fabrication of fiberglass-reinforced plastic pressure vessels. The fabrication processes are limited to the Bag-Molding, Centrifugal-Casting and Filament-Winding Processes.

F-110 PROCEDURE SPECIFICATIONS

(*a*) For every fabrication method employed in producing vessels to be marked with the Code symbol, the manufacturer shall prepare a Procedure Specification which shall be qualified in accordance with Part Q of this Section before being employed to produce vessels to be so marked.

(*b*) Any essential variation from the Procedure Specification (see Pars. Q-200, Q-300 and Q-400) shall require that the Procedure Specification be rewritten and requalified before being employed to produce vessels to be marked with the Code symbol.

ARTICLE F-2
SPECIAL FABRICATION REQUIREMENTS FOR BAG-MOLDING PROCESS

F-200 GLASS CONTENT

The composite structure shall consist of short length[1] glass filaments in a resin matrix. The weight of the fiberglass reinforcement shall conform to that set forth in the qualified Procedure Specification (see Form Q-106) within a tolerance of plus 20 percent and minus 0 percent. The weight of the glass reinforcement in supplementary pads which are used to give greater wall thickness at openings shall not be less than 35 percent of the total weight of the pads.

F-201 Glass Composition

Type E glass conforming to the composition stipulated in Par. M-110 shall be used for reinforcement.

F-203 Sizing

See Par. M-110.2.

F-210 FORM OF FIBERGLASS REINFORCEMENT

(*a*) The fiberglass reinforcement shall consist of mats or preforms made from chopped fiberglass strands. The percentage of resin binder shall not exceed 10 percent by weight in mat or preform.

(*b*) The flat mats for cylindrical reinforcement shall be laid up in a staggered pattern and rolled on a mandrel prior to assembly into the mold (see Fig. F-210.1).

(*c*) The head or end preforms shall be made by depositing chopped glass fiber from an air stream with a suitable epoxy or polyester resin binder dispersed in the fiber (see Fig. F-210.2).

F-215 Resin System

The resin system shall be either an epoxy system or a polyester system as required for the particular service conditions specified and by the qualified procedure specification. No filler, pigment or dye additions shall be used which will interfere with translucent visual inspection.

F-216 Cure

The design and operation of the curing equipment shall assure uniform heating over the entire surface of the pressure vessel. The curing time and temperature shall conform to those stipulated in the qualified Procedure Specification (see Form Q-106).

F-220 MOLDS

F-221 Mold Material

The molds for pressure bag-molding of pressure vessels may be fabricated of any material or combination of materials. The molds shall have sufficient dimensional stability to withstand the bag pressure loads during the forming and cure cycles.

[1] Short length is that produced by cutter blades with not less than 1 in. nor more than 4 in. spacing.

F-222 Mold Release Agent

The surface of the mold in contact with the vessel shall be treated with a suitable release agent to facilitate removal of the vessel from the mold. Such release agent shall not be detrimental to the vessel walls.

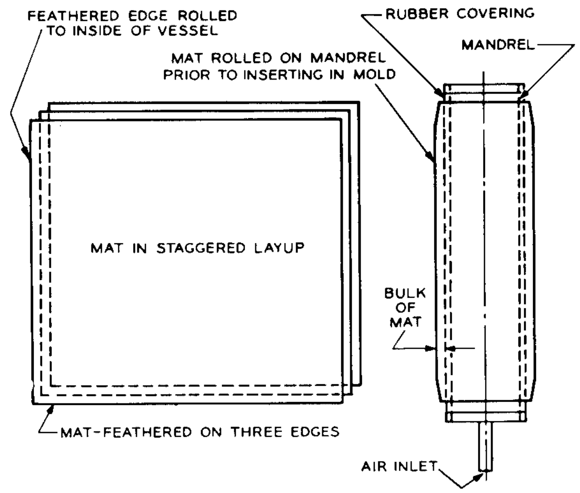

FIG. F-210.1 FIBERGLASS SIDE WALL LAYUP FOR BAG-MOLDING

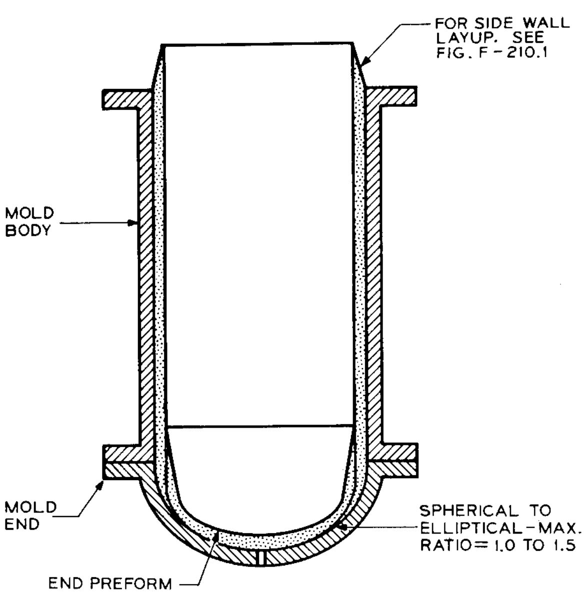

FIG. F-210.2 HEAD OR END PREFORM FOR CYLINDRICAL VESSEL

F-223 Mold Removal

The mold may be removed from the vessel, or vice versa, by any technique which will not damage the vessel wall.

F-225 Pressure Bags

The pressure bags used to compress the fiberglass mats and preforms and to hold the glass and resin in position during the curing cycle may be made of any flexible material that the molding resin will not attack, or which can be protected from such attack by a suitable material.

F-230 LINERS

F-231 Liner Material

Liners, when used, may be made of elastomeric or plastic material. When such liner materials are employed, the liner may be used as the pressure bag. Alternatively, liners may be applied to the completed vessel.

F-232 Provisions in Liners for Openings in Vessels

Liners shall be designed so that they extend completely through all access openings in the vessel.

F-240 OPENINGS IN VESSEL

The number, size and location of openings in bag-molded vessels shall meet the requirements of the User's Design Specification. The adequacy of reinforcement, if any, for such openings shall be determined by the tests required by Par. D-160 to prove design adequacy.

F-250 MOLDED-IN FITTINGS

Openings less than 1½ in. nominal pipe size may be produced by molding around a removable insert.

ARTICLE F-3 SPECIAL FABRICATION REQUIREMENTS FOR CENTRIFUGAL-CASTING PROCESS

F-300 GLASS CONTENT

The composite structure shall consist of random short length[1] glass filaments in a resin matrix. The weight of the fiberglass reinforcement shall conform to that set forth in the qualified Procedure Specification (see Form Q-106) within a tolerance of plus 10 percent and minus 0 percent. The weight of the glass reinforcement in supplementary pads which are used to give greater wall thickness at openings shall not be less than 35 percent of the total weight of the pads.

F-301 Glass Composition

Type E glass conforming to the composition stipulated in Par. M-110 shall be used for reinforcement.

F-303 Sizing

See Par. M-110.2.

F-310 FORM OF REINFORCEMENT

The fiberglass reinforcement for centrifugally cast cylinders shall consist of chopped fiberglass strands or rovings. Fabrication of heads shall conform to Par. F-210(c).

F-315 Resin System

The resin system shall be either an epoxy system or a polyester system as required for the particular service conditions specified and by the qualified Procedure Specification. No filler, pigment or dye additions shall be used which will interfere with translucent visual inspection.

F-316 Cure

The design and operation of the curing equipment shall assure uniform heating over the entire cylinder. The curing time and temperature shall conform to those stipulated in the qualified Procedure Specification (see Form Q-106).

F-320 MANDRELS

F-321 Mandrel Material

The mandrel shall be fabricated of any material or combination of materials of sufficient rigidity and dimensional stability to withstand the centrifugal-casting loads and the curing cycle.

[1]Random short length is that produced by cutter blades with not less than 1 in. nor more than 4 in. spacing.

F-322 Mandrel Release Agent

The mandrel shall be treated with a suitable release agent to facilitate removal of the cured pressure cylinder. Such release agent shall not be detrimental to the cylinder.

F-323 Mandrel Removal

The cylinder may be removed from the mandrel, or vice versa, by any technique which will not damage the cylinder walls.

F-325 Matched-Die-Molded Heads

Matched-die-molded heads used as closures for centrifugally cast cylinders shall be fabricated in accordance with the requirements of Article F-2 for the bag-molding process. Conventional die-molding techniques may be used for molding the heads.

F-330 LINERS

F-331 Liner Material

Liners, when used, may be made of elastomeric or plastic materials. The liner may be applied to the centrifugally cast cylinder after its heads are attached by adhesive bonding.

F-332 Provisions in Liners for Vessel Openings

Liners shall be designed so that they extend completely through all access openings in the vessel.

F-340 OPENINGS IN VESSEL

The number, size and location of openings in centrifugally cast cylinders and attached heads shall meet the requirements of the User's Design Specification. The adequacy of reinforcement, if any, for such openings shall be determined by the tests required by Par. D-160 to prove design adequacy.

ARTICLE F-4
SPECIAL FABRICATION REQUIREMENTS FOR FILAMENT-WINDING PROCESS

F-400 GLASS CONTENT

The composite structure shall consist of continuous glass strands in a resin matrix. The weight of the fiberglass reinforcement shall conform to that set forth in the qualified Procedure Specification (see Form Q-107 at the end of this Section) within a tolerance of plus 10 percent and minus 0 percent. The weight of the glass reinforcement in supplementary pads which are used to give greater wall thickness at openings shall not be less than 35 percent of the total weight of the pads.

F-401 Glass Composition

Type E glass filaments conforming to the composition stipulated in Par. M-110 shall be used for reinforcement of filament-wound pressure vessels.

F-403 Sizing

See Par. M-110.2.

F-410 FORM OF REINFORCEMENT

F-410.1 **Patterns** Specific winding patterns for the continuous glass strands shall be used as defined in the qualified Procedure Specification (see Form Q-107). Any winding pattern which places the filaments in the desired orientation may be used.

F-410.2 **Alignment with Stresses** In general, the patterns shall be so arranged that the stressed filaments are aligned to resist the principal stresses which result from internal pressure and other loadings.

F-410.3 **Wall Thickness** The wall thickness is governed by the number of layers of wound strands of filaments required for the particular vessel.

F-415 Resin System

The resin system shall be either an epoxy system or a polyester system as required for the particular service conditions specified and by the qualified Procedure Specification. No filler, pigment or dye additions shall be used which will interfere with translucent visual inspection.

F-416 Cure

The design and operation of the curing equipment shall assure uniform heating over the entire surface of the pressure vessel. Heating may be done from the inside or outside of the pressure vessel or from both inside and outside. The cure time and temperature shall conform to those stipulated in the qualified Procedure Specification (see Form Q-107).

F-417 Filament Winding

(*a*) *Tensioning* Tension on the strands of filaments during the winding operation shall be controlled to assure uniformly stressed filaments in the composite wall as specified in the qualified Procedure Specification.

(*b*) *Winding Speed* The speed of winding shall be limited only by the ability to meet the tensioning requirements, to conform to the specified winding pattern and to insure adequate resin impregnation.

(*c*) *Band Width and Spacing* The band width and spacing shall conform to those specified in the qualified Procedure Specification.

F-420 MANDRELS

F-421 Mandrel Material

The mandrel may be fabricated of any material or combination of materials with sufficient rigidity and dimensional stability to resist the winding loads and the compressive loads on the mandrel which occur during the cure cycle.

F-422 Mandrel Release Agent

The mandrel, if removed, may be treated with a suitable release agent to facilitate its removal from the cured pressure vessel. Such release agent shall not be detrimental to the finished vessel.

F-423 Mandrel Removal

The mandrel may be removed by any technique which will not damage the filament-wound composite or the liner, if one is present.

F-430 LINERS

F-431 Liner Material

Liners, when used, may be made of elastomeric, plastic or metallic materials. The liner may be applied to the mandrel prior to the start of the winding operation.

(*a*) If applied to the mandrel before the winding operation begins, the thickness and hardness of the liner material shall be such that the filament orientation and tension will not be adversely affected by deflection or "flow" of the liner material.

(*b*) Alternatively, the liner may be applied to the completed, filament-wound pressure vessel, in which case the restrictions on thickness and hardness do not apply.

(*c*) If the liner is required to be bonded to the filament-wound composite, the outer liner surface shall be treated to facilitate such bonding.

(*d*) The design of metallic liners shall take into account the pronounced difference in the moduli of elasticity of the laminate and the metallic liner.

F-432 Provisions in Liners for Vessel Openings

Liners shall be designed so that they extend completely through all access openings in the vessels.

F-440 OPENINGS IN VESSELS

The number, size and location of openings in filament-wound pressure vessels shall meet the requirements of the User's Design Specification. The adequacy of reinforcement, if any, for such openings shall be determined by the tests required by Par. D-160 to prove design adequacy.

ARTICLE F-5
SPECIAL REQUIREMENTS FOR ADHESIVE-BONDING

F-500 PROCEDURE SPECIFICATIONS AND QUALIFICATIONS

(*a*) When the fabricating process used to produce a vessel to be marked with the Code symbol includes adhesive-bonding of parts such as heads, etc. or when it is desired to join two or more cylinders to produce a long shell, the Procedure Specification shall include full details of the adhesive-bonding process. Any variation in the design of the joints being bonded, outside of those inherent in the process of forming the surfaces to be bonded, and any variation in the adhesive used and its curing temperature and time, all of which shall be set forth in the Procedure Specification, shall require requalification of the design and/or the Procedure Specification.

(*b*) Longitudinal seams, including adhesive-bonded seams, in cylindrical vessels are not permitted.

PART Q
RULES FOR QUALIFYING DESIGNS AND PROCEDURES

ARTICLE Q-1
SCOPE

Q-100 RESPONSIBILITY FOR QUALIFICATION

Each Manufacturer shall be responsible for qualifying the designs and the Procedure Specifications used in fabricating fiberglass-reinforced plastic pressure vessels and parts of vessels.

Q-105 Fabrication Processes

The fabrication processes which may be qualified under this Section of the Code shall be restricted to Bag-Molding[1], Centrifugal-Casting, and Filament-Winding.

Q-106 Production Work without Qualification

No production work shall be undertaken until the design and a written Procedure Specification have been qualified by the Manufacturer. (See Pars. Q-110 and Q-120)

Q-110 MAINTENANCE OF PROCEDURE SPECIFICATION AND QUALIFICATION RECORDS

The Manufacturer shall maintain specifications of the procedures he employs in fabricating vessels and vessel parts and in bonding vessel parts together. He shall also maintain records of the tests by which his Procedure Specifications are qualified for use in producing vessels. Such records shall be dated and shall be certified to by the Manufacturer and the Inspector (see Par. I-110). The Manufacturer shall keep these records on file for at least five years and in the case of mass-produced vessels for at least five years after the production of such vessels has ceased.

Q-120 PROCEDURE SPECIFICATION QUALIFICATION FORMS

Recommended forms showing the information required in qualifying the design and the Procedure Specification are provided as Form Q-106 for fabrication by Bag-Molding and Centrifugal-Casting, Form Q-107 for fabrication by Filament-Winding, and Form Q-115 for fabrication by Adhesive-Bonding.

Q-130 MEANS TO BE USED IN QUALIFYING DESIGNS AND FABRICATING PROCEDURES

In qualifying vessel designs and fabrication

[1]Matched-die-molded parts are acceptable under this Section as being equivalent to bag-molded parts when using the same type of fiberglass reinforcement and the same resin system.

procedure qualifications, the qualification checks listed in Par. Q-130.1 and the qualification tests listed in Par. Q-130.2 shall be employed.

Q-130.1 Qualification Checks[1] The following checks (see Arts. Q-2, Q-3 and Q-4 for special requirements) shall be applied to the prototype vessels:

(*a*) *Visual Check* The vessels shall be visually checked for imperfections which might lead to premature failure (see Par. T-214);

(*b*) *Thickness Check* The thickness of the vessels at a minimum of 12 points shall be checked by mechanical gages and/or ultrasonic equipment (see Par. T-340);

(*c*) *Composition Check* The percent of glass and resin by weight, constituting the laminate, shall be determined (see Par. T-212);

(*d*) *Weight Check* The weight of the whole vessel shall be determined and shall be not less than 95 percent of that stated in the Procedure Specification.

Q-130.2 Qualification Tests[1] The following tests shall be applied to the prototype vessel or vessels or parts thereof:

(*a*) *Barcol hardness test (see Par. T-221),* which is useful in verifying that the laminate has been cured in accordance with the Procedure Specification;

(*b*) *Volumetric expansion test* which indicates that the laminate used has a modulus of elasticity within the range intended by the designer;

NOTE: In lieu of measuring the volumetric change of the vessel by determining the difference in volumes of fluid it will contain at the design pressure and at atmospheric pressure, it is permissible to check the circumference of the vessel at a minimum of three points evenly spaced along its length. The distance between such reference points shall not exceed five feet. The measurement shall be made at both atmospheric pressure and design pressure and shall show no permanent distortion.

(*c*) *Hydrostatic bursting pressure test* by which the design pressure (one-sixth of the bursting pressure) is determined;

(*d*) *Cyclic pressure plus hydrostatic bursting pressure test* (i.e., 100,000 cycles at the design pressure and 150 F followed by a burst test by which it is demonstrated that the vessel has no inherent stress-concentration or discontinuities which will cause it to fail in bonding);

(*e*) *Suitable tests, utilizing loads simulating the expected loadings* of vessels subject to bending and shearing, caused by any expected combination of loadings listed in Par. D-120, shall be applied to qualify such vessels.

[1] See Article T-2 for detailed requirements governing the conducting of these checks and tests.

ARTICLE Q-2
SPECIAL REQUIREMENTS FOR BAG-MOLDING PROCEDURE QUALIFICATION

Q-200 ESSENTIAL VARIABLES[1]

Essential variables listed in Form Q-106, Recommended Form for Qualifying the Vessel Design and the Procedure Specification Used in Fabricating Bag-Molded and Centrifugally Cast Fiberglass-Reinforced Plastic Pressure Vessels, deviation from which shall require requalification of a procedure, are:

(*a*) Type of fiberglass;

(*b*) Composition of sizing;

(*c*) Percent of fiberglass outside range established in the Procedure Specification;

(*d*) Weight of vessel outside range established in the Procedure Specification;

(*e*) Composition of resin;

(*f*) Composition of curing agent;

(*g*) Curing schedule (i.e., time, temperature or pressure);

(*h*) Barcol Hardness, outside range established in the Procedure Specification;

(*i*) Volumetric expansion, outside range established in the Procedure Specification.

[1] Essential variables shall be held within tolerances established elsewhere in this Section.

Q-201 Nonessential Variables

Changes in variables other than those listed in Par. Q-200 are considered nonessential. They may be made without requalification of a procedure, provided the Procedure Specification is modified to show the changes.

ARTICLE Q-3
SPECIAL REQUIREMENTS FOR CENTRIFUGAL-CASTING PROCEDURE QUALIFICATION

Q-300 ESSENTIAL VARIABLES[1]

Essential variables listed in Form Q-106; Recommended Form for Qualifying the Vessel Design and the Procedure Specification Used in Fabricating Bag-Molded and Centrifugally Cast Fiberglass-Reinforced Plastic Pressure Vessels, deviation from which shall require requalification of a procedure, are:

(*a*) Type of fiberglass;

(*b*) Composition of sizing;

(*c*) Percent of fiberglass outside range established in the Procedure Specification;

(*d*) Weight of vessel outside range established in the Procedure Specification;

(*e*) Composition of resin;

(*f*) Speed of rotation when casting;

(*g*) Composition of curing agent;

(*h*) Curing schedule (i.e., time, temperature or pressure);

(*i*) Barcol Hardness, outside range established in the Procedure Specification;

(*j*) Volumetric expansion, outside range established in the Procedure Specification.

Q-301 Nonessential Variables

Changes in variables other than those listed in Par. Q-300 are considered nonessential. They may be made without requalification of a procedure, provided the Procedure Specification is modified to show the changes.

[1] Essential variables shall be held within tolerances established elsewhere in this Section.

ARTICLE Q-4
SPECIAL REQUIREMENTS FOR FILAMENT-WINDING PROCEDURE QUALIFICATION

Q-400 ESSENTIAL VARIABLES[1]

Essential variables listed in Form Q-107, Recommended Form for Qualifying the Vessel Design and the Procedure Specification Used in Fabricating Filament-Wound Fiberglass-Reinforced Plastic Pressure Vessels, deviation from which shall require requalification of a procedure, are:

(*a*) Type of fiberglass;
(*b*) Composition of sizing;
(*c*) Manner of impregnation;
(*d*) Weight of vessel outside range established in the Procedure Specification;
(*e*) Winding tension, outside range established in the Procedure Specification;
(*f*) Variables of winding process;
(*g*) Composition of resin;
(*h*) Composition of curing agent;
(*i*) Curing schedule (i.e., time, temperature or pressure);
(*j*) Liner;
(*k*) Pole pieces;
(*l*) Barcol Hardness, outside range established in the Procedure Specification;
(*m*) Volumetric expansion, outside range established in the Procedure Specification.

Q-401 Nonessential Variables

Changes in variables other than those listed in Par. Q-400 are considered nonessential. They may be made without requalification of a procedure, provided the Procedure Specification is modified to show the changes.

[1] Essential variables shall be held within tolerances established elsewhere in this Section.

PART R
PRESSURE-RELIEF DEVICES

ARTICLE R-1
GENERAL REQUIREMENTS

R-100 PROTECTION AGAINST OVERPRESSURE

(*a*) All pressure vessels within the scope of this Section shall be provided with protection against overpressure in accordance with the requirements of Paragraph R-130.

(*b*) Heat Exchangers and similar vessels shall be protected against overpressure in case of an internal failure.

R-110 TYPES OF OVERPRESSURE PROTECTION

Protection against overpressure shall be provided by one or a combination of the following devices or methods:

(*a*) Direct spring-loaded safety or safety-relief valves;

(*b*) Indirectly operated safety or safety-relief valves, such as pilot-operated valves;

(*c*) Rupture disks.

R-120 SET PRESSURES

R-121 For a Single Pressure-Relief Device

A single pressure-relief device shall be set to operate at a pressure (see Par. R-125 for tolerances) not exceeding the design pressure of the vessel at the operating temperature except as permitted in Par. R-122.

R-122 For Multiple Pressure-Relief Devices

If the required discharging capacity is supplied by more than one device, only one need be set to operate at a pressure not exceeding the design pressure of the vessel; the additional device or devices may be set at a higher pressure but not to exceed 105 percent of the design pressure of the vessel.

R-123 Pressure Effects to be Included in Setting

The pressure at which any device is set to open shall include the effects of static head and back pressure.

R-125 Set Pressure Tolerances

Set pressure tolerances as stated in Pars. R-125.1 and R-125.2 are sufficiently restrictive so that the nominal set-to-operate pressure of the overpressure protection device may equal the design pressure of the vessel.

R-125.1 For Safety and Safety-Relief Valves Safety and safety-relief valves shall have a set pressure tolerance of plus or minus 2 psi for pressures up to and including 70 psi and of plus

or minus 3 percent for pressures exceeding 70 psi.

R-125.2 For Rupture Disks Rupture disks shall have a rupture pressure tolerance of plus or minus 5 percent at all pressures.

R-130 PERMISSIBLE OVERPRESSURES

The aggregate capacity of the pressure-relief devices shall be sufficient to prevent overpressure in excess of those specified in (a) and (b) when the pressure-relief devices are discharging.

(*a*) The permissible overpressure for all pressure vessels constructed according to this Section shall be limited to 110 percent of the design pressure when the safety-relief valves are discharging except when the overpressure is caused by conditions listed in Par. R-130(b).

(*b*) The permissible overpressure shall be limited to 120 percent of the design pressure when the safety-relief valves are discharging for conditions such as exposure to fire or other unexpected sources of external heat.

ARTICLE R-2
MATERIAL AND DESIGN REQUIREMENTS

R-200 MATERIAL REQUIREMENTS

Pressure-relief devices shall be constructed of materials suitable for the pressure, temperature and other conditions of the service intended.

R-200.1 Restrictions on Use of Cast Iron Seats or disks of cast iron shall not be used.

R-210 DESIGN REQUIREMENTS

R-211 Minimum Size of Safety-Relief Valves

Any safety-relief valve used for relieving liquid shall be at least ½ in. iron pipe size.

R-212 Lifting Devices

(*a*) Safety and safety-relief valves for steam or air service shall be provided with a substantial lifting device so that the disk can be lifted from its seat when the pressure in the vessel is 75 percent of that at which the valve is set to open.

(*b*) Safety and safety-relief valves for service other than steam and air need not be provided with a lifting device, although a lifting device is desirable if the vapors are such that their release will not create a hazard.

R-213 Drain Requirements

If the design of a safety or safety-relief valve is such that liquid can collect on the discharge side of the disk, the valve shall be equipped with a drain at the lowest point where liquid can collect.

R-214 Requirements for Indirectly Operated Valves

Design of pilot-operated valves or other indirectly operated valves shall be such that the main unloading valve will open automatically at the set pressure (within tolerances as stated in Par. R-125) and will discharge its full rated capacity if some essential part of the pilot or auxiliary device should fail.

ARTICLE R-3
MARKING AND STAMPING

R-300 MARKING

R-301 Safety and Safety-Relief Valves

Each safety and safety-relief valve, ½ in. pipe size and larger, shall be plainly marked by the manufacturer with the required data in such a way that the marking will not be obliterated in service. Smaller valves may be exempted from these marking requirements. The marking may be placed on the valve or on a plate or plates securely fastened to the valve. The Code symbol shall be marked on the valve or nameplate, but the other required data may be marked, etched, impressed, or cast on the valve or nameplate. The marking shall include the following:

(*a*) The name or identifying trademark of the manufacturer;

(*b*) Manufacturer's design or type number;

(*c*) Size________ in. (The pipe size of the valve inlet);

(*d*) Set pressure______________ psi;

(*e*) Capacity________ lb. of saturated steam per hour, or________ cu. ft. of air (60 F and 14.7 psia) per minute;

NOTE: In addition, the manufacturer may indicate the capacity in other fluids (see Appendix 2);

(*f*) ASME symbol as shown in Fig. R-301.1.

FIG. R-301.1 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD

R-301.1 Safety and Safety-Relief Valves Certified for Steam-Discharging Capacity Safety and safety-relief valves certified for a steam-discharging capacity under the provisions of Section I of the Code and bearing the official Code symbol stamp of that Section of the Code for safety valves, may be used on fiberglass reinforced plastic pressure vessels. The rated capacity in terms of other fluids shall be determined by the method of conversion given in Appendix 2 (see Par. R-450).

R-302 Safety-Relief Valves

Each safety-relief valve used for relieving liquid shall be marked with the following data:

(*a*) Name or identifying trademark of the manufacturer;

(*b*) Manufacturer's design or type number;

(*c*) Size________ in. (pipe size of inlet);

(*d*) Set pressure______________ psi;

(*e*) Relieving capacity___________ gal. of water per minute at 70 F.

R-303 Rupture Disks

Every rupture disk shall be plainly marked by the manufacturer in such a way that the marking will not be obliterated in service. The marking may be placed on the flange of the disk or on a metal tab permanently attached thereto[1]. The marking shall include the following:

(*a*) The name or identifying trademark of the manufacturer;

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[1] The marking may be coded and identified with the marking given on the certificate supplied with each rupture disk.

(*b*) Manufacturer's design or type number and lot number;

(*c*) Size________ in.;

(*d*) Maximum bursting pressure__________ psi;

(*e*) Minimum bursting pressure__________ psi;

(*f*) Coincident disk temperature_________ F;

(*g*) Capacity__________ lb. of saturated steam per hour, or__________ cu. ft. of air (60 F and 14.7 psia) per minute.

NOTE: In addition the manufacturer may indicate the capacity in other fluids (see Appendix 2).

R-310 USE OF CODE SYMBOL STAMP

Each safety and safety-relief valve to which the Code symbol is to be applied shall be fabricated by a manufacturer who is in possession of a Code symbol stamp (see Fig. R-301.1) and a valid certificate of authorization obtainable when the conditions of Pars. R-311 through R-316 have been complied with.

R-311 Authorization to Use Stamp

Authorization to use the Code symbol stamp referred to in Par. R-301 will be granted by the Society pursuant to the provisions of Pars. R-312 through R-316.

R-312 Application for Stamp

Any manufacturer may apply to the Boiler and Pressure Vessel Committee of the Society in writing, upon forms issued by the Society, for permission to use the stamp. Each applicant must agree that, if permission to use the stamp is granted, it will be used according to the rules and regulations of this Code, that any safety or safety-relief valve to which the symbol is applied will have the certified capacity marked upon the valve after tests as required in Par. R-400, and that any stamp will be promptly returned to the Society upon demand, or in case the applicant discontinues the manufacture of safety and safety-relief valves to which the Code Symbol is applied, or in case the certificate of authorization issued to such applicant has expired and no new certificate has been issued. The holder of any such stamp shall not permit any other manufacturer to use his stamp.

R-313 Certificate of Authorization

Permission to use the stamp may be granted or withheld by the Society in its absolute discretion. If authorization is given, and the proper administrative fee is paid, a Certificate of Authorization evidencing permission to use such a symbol, expiring on the triennial anniversary date thereafter, will be forwarded to the applicant. Each such certificate will be signed by the Chairman and Secretary, or other duly authorized officer or officers, of the Boiler and Pressure Vessel Committee. Six (6) months prior to the date of expiration of any such certificate, the applicant must apply for a renewal of such permission and the issuance of a new certificate.

R-314 Right of Society to Cancel or Refuse Renewal of Authorization

The Society reserves the absolute right to cancel or refuse to renew such permission, returning fees paid for the pro-rated unexpired term.

R-315 Regulations Concerning Issuance and Use of Stamp

The Boiler and Pressure Vessel Committee may at any time and from time to time make such regulations concerning the issuance and use of such stamps as it deems appropriate, and all such regulations shall become binding upon the holders of any valid certificates of authorization.

R-316 Obtaining of Stamps

All steel stamps for applying the symbol shall be obtained from the Society.

ARTICLE R-4
CERTIFICATION OF CAPACITY OF SAFETY AND SAFETY-RELIEF VALVES

R-400 CERTIFICATION OF CAPACITY BEFORE APPLYING SYMBOL

Before the symbol is applied to any safety or safety-relief valve, the valve manufacturer shall have the capacity of the valves certified as prescribed in Pars. R-421, R-422 and R-423.

R-410 FLUID MEDIA AND TEST PRESSURES

R-411 Fluid Media for Capacity Certification Tests

Capacity certification tests shall be conducted on saturated steam, air or natural gas. When saturated steam is used, corrections for moisture content of the steam shall be made.

R-412 Maximum Test Pressure

Capacity certification tests shall be conducted at a pressure not to exceed 110 percent of the pressure for which the safety or safety-relief valve is set to operate. The reseating pressure shall be noted and recorded.

R-413 Tests of Pilot-Operated Valves

Capacity certification of pilot-operated safety and safety-relief valves may be based on tests without the pilot valves installed, provided prior to capacity tests it has been demonstrated by test to the satisfaction of the authorized observer that the pilot valve will cause the main valve to fully open within 110 percent of the set pressure of the main valve and that the pilot valve in combination with the main valve will meet all the requirements of the Code.

R-420 PROCEDURES FOR CAPACITY CERTIFICATION TESTS

R-421 Three-Valve Method

A capacity certification test is required on a set of three valves for each combination of size, design and pressure setting. The marked capacity rating for each combination of design, size and test pressure shall be 90 percent of the average capacity of the three valves tested.

NOTE: The capacity of a set of three valves shall fall within a range of plus or minus 5 percent of the average capacity. Failure to meet this requirement shall be cause to refuse certification of that particular safety valve design.

R-422 Curve Method

If a manufacturer wishes to apply the Code symbol to a design of safety or safety-relief valves, four valves of each combination of pipe size and orifice size shall be tested. These four valves shall be set at pressures which will cover the approximate range of pressures for which the valves will be used. The capacities, as deter-

mined by these four tests, shall be plotted against the absolute flow test pressure and a curve drawn through these four points. If the four points do not establish a reasonable curve, the authorized observer shall require that additional valves be tested. From this curve, relieving capacities shall be obtained. The stamped capacity shall be 90 percent of the capacity taken from the curve.

R-423 Coefficient-of-Discharge Method

Instead of individual capacity certification as provided in Pars. R-421 and R-422 a coefficient of discharge K may be established for a specific safety valve design according to the procedure in subparagraphs (a), (b) and (c).

(*a*) For each design the safety valve manufacturer shall submit for test at least three valves for each of three different sizes (a total of nine valves) together with detailed drawings showing the valve construction. Each valve of a given size shall be set at a different pressure.

(*b*) Tests shall be made on each safety or safety-relief valve to determine its capacity-lift, popping and blow-down pressures and actual capacity in terms of the fluid used in the test. Valves having an adjustable blow-down construction shall be adjusted prior to testing so that the blow-down does not exceed 5 percent of the set pressure. A coefficient K_D shall be established for each test run as follows:

$$K_D = \frac{\text{Actual Flow}}{\text{Theoretical Flow}} = \text{Coefficient of discharge}$$

where Actual Flow is determined quantitatively by test, and Theoretical Flow is calculated by the appropriate formula which follows:

For Test with Dry Saturated Steam:

$$W_T = 51.5\ AP$$

For Test with Air

$$W_T = 356\ AP\sqrt{\frac{M}{T}}$$

For Test with Natural Gas

$$W_T = CAP\sqrt{\frac{M}{ZT}}$$

where

W_T = theoretical flow, pounds per hour

A = actual discharge area through the valve at developed life, square inches

P = (set pressure × 1.10) plus atmospheric pressure, psia

M = molecular weight

T = absolute temperature at inlet (degrees Fahrenheit plus 460)

C = constant for gas or vapor based on the ratio of specific heats

$= \dfrac{C_p}{C_v}$ (see Fig. 2-100.1)

Z = compressibility factor corresponding to P and T

The average of the coefficients K_D of the nine tests required shall be multiplied by 0.90 and this product shall be taken as the coefficient K of that design.

NOTE: All experimentally determined coefficients, K_D, shall fall within a range of plus or minus 5 percent of the average K_D found. Failure to meet this requirement shall be cause to refuse certification of that particular valve design.

(*c*) The official relieving capacity of all sizes and pressures of a given design, for which K has been established under the provisions of (b), that are manufactured subsequently, shall then be calculated by the appropriate formula in (b) multiplied by the coefficient K (see Appendix 2).

R-430 WHERE AND BY WHOM CAPACITY TESTS SHALL BE CONDUCTED

(*a*) Tests shall be conducted at a place where approved equipment and personnel are available to conduct pressure-relieving capacity tests. Tests shall be made in the presence of and certified by an authorized observer. The place, personnel, equipment, and the authorized observer shall be subject to approval by the Boiler and Pressure Vessel Committee.

(*b*) Laboratory approval is subject to review within each five year period.

R-440 TEST DATA REPORTS

A data report for each safety valve tested shall be filled out and signed by the manufacturer and

by the authorized observer witnessing the tests (a sample data report appears in the Appendix, as Form RP-3). Such data report will be the manufacturer's authority to stamp valves of corresponding design, size and pressure range. When changes are made in the design, the certification test must be repeated.

R-450 WAIVER OF FURTHER TESTS OF VALVES TESTED PER SECTION I

It shall be permissible to rate safety valves under Par. PG-69.2 of Section I with capacity ratings at 103 percent of flow, for use on fiberglass reinforced plastic pressure vessels, without further test. In such instances, the capacity rating of the valve may be increased to allow for the flow pressure permitted in Par. R-412, namely, 110 percent, by the multiplier

$$\frac{1.10\,p + 14.7}{1.03\,p + 14.7}$$

where p = set pressure, psi, gage.

Such valves shall be marked in accordance with Par. R-301. This multiplier shall not be used as a divisor to transform test ratings from a higher to a lower flow.

ARTICLE R-5
PROVISIONS IN VESSELS FOR INSTALLATION OF PRESSURE-RELIEF DEVICES

R-500 NUMBER, SIZE AND LOCATION OF CONNECTIONS

R-501 Connections for Vapor-Relief Valves

Vessels shall have at least one connection, in the vapor space, for directly mounted pressure-relief devices, or for piping to pressure-relief devices, open paths or vents.

R-502 Connections for Safety-Relief Valves

A connection below the normal liquid level shall be provided for a safety-relief valve, if the latter is to be used.

R-510 SIZE OF OPENINGS AND NOZZLES

Openings and nozzles constituting the connections specified in Pars. R-501 and R-502 shall have sufficient flow capacity to permit the pressure-relief device or system to maintain overpressure limits.

R-511 Openings through Connecting Pipe and Fittings

The opening through all pipe and fittings between a pressure vessel and its pressure-relief device shall have at least the area of the pressure-relief device inlet and in all cases shall have sufficient area so as not to unduly restrict the flow to the pressure-relief device. The opening in the vessel wall shall be designed to provide direct and unobstructed flow between the vessel and its pressure-relief device.

R-512 Multiple Relief Devices on One Connection

When two or more required pressure-relief devices are placed on one connection, the inlet internal cross-sectional area of this connection shall be at least equal to the combined inlet areas of the safety devices connected to it and in all cases shall be sufficient so as not to restrict the combined flow of the attached devices.

R-515 Stop Valves between Vessel and Pressure-Relief Devices

There shall be no intervening stop valves between the vessel and its pressure-relief device or devices, or between the pressure-relief device or devices, and the point of discharge, except:

(*a*) When the stop valves are so constructed or positively controlled that the closing of the maximum number of stop valves possible at one time will not reduce the pressure-relief capacity provided by the unaffected relieving devices below the required relieving capacity; or

(*b*) Under the conditions set forth in Appendix 3.

R-520 LOCATION OF OPENINGS AND CONNECTIONS

Openings and connections for pressure-relief purposes shall be so located that the nature of the vessel's contents will not hinder flow through such openings and connections.

R-530 DISCHARGE LINES FROM PRESSURE-RELIEF DEVICES

Discharge lines from pressure-relief devices shall be designed to facilitate drainage or shall be fitted with an open drain to prevent liquid lodging in the discharge side of the safety device and such lines shall lead to a safe place of discharge. The size of the discharge lines shall be such that any pressure that may exist or develop will not reduce the relieving capacity of the relieving devices below that required to properly protect the vessel (see Par. R-213 and Appendix 3).

PART T
RULES GOVERNING TESTING

ARTICLE T-1
TESTING REQUIREMENTS

T-100 SCOPE

Tests to be made relative to vessels to be marked with the Code symbol shall consist of Qualification Tests, Quality Control Tests and Production Tests. Such tests shall conform to the requirements of this Part T.

T-110 MANUFACTURER'S RESPONSIBILITY

The manufacturer completing a vessel to be marked with the Code symbol has the responsibility of conducting the tests stipulated in this Part and to do so in strict accordance with its requirements in order to assure that such vessel is adequately designed for the specified service conditions to be marked on it and that the procedure for fabricating it, as described in the Procedure Specification to which it is constructed, is adequate to produce such a vessel.

T-111 Test Report

The manufacturer has the responsibility of preparing and keeping on file, for at least five years (see Par. G-321 (f)), a detailed report of the tests he has conducted to prove that the design of each vessel to be marked with the Code symbol and the Procedure Specification under which it was fabricated are such as to assure that it is adequate for the specified service conditions. The test report shall be certified by the Manufacturer and the Inspector.

T-120 INSPECTOR'S DUTY

See Par. I-130.

ARTICLE T-2
DESIGN AND PROCEDURE QUALIFICATION TEST REQUIREMENTS

T-200 GENERAL

The tests and examinations stipulated in this Article are intended to qualify both the design of a prototype vessel, and the Procedure Specification in accordance with which it has been produced. Production vessels, which conform in design to the prototype vessel and which are fabricated in accordance with the qualified Procedure Specification, may be marked with the Code symbol, after the Inspector has assured himself that all the provisions of this Code have been complied with (see Par. G-321).

T-210 QUALIFICATION CHECKS AND EXAMINATIONS

Each prototype vessel shall be checked and examined in accordance with the requirements of Pars. T-211 through T-214 and the results shall be recorded in the Manufacturer's Design Report.

T-211 Vessel Thickness

The thickness of each prototype vessel shall be determined at a minimum of three points along its length on each of its four quadrants. When vessels are longer than 5 feet, one additional determination shall be made for each additional 5 feet or portion thereof. The thickness determinations shall be made with mechanical gages, ultrasonic gages or other devices having an accuracy of within plus or minus 2 percent of true thickness.

(*a*) Where visual indication of deviation from design thickness exists at points other than those at which measurements are required, thickness determinations in sufficient number to properly locate and define the deviant area shall be made.

T-212 Weight of Resin and Glass

The percentage by weight of resin and fiberglass in each prototype vessel shall be determined by means of an ignition test per ASTM D-2584-67T of a sample taken from an undamaged portion of the burst vessel.

T-213 Vessel Weight

Each prototype vessel shall be weighed within an accuracy of plus or minus 1 percent.

T-214 Visual Examination of Vessels

Each prototype vessel shall be visually examined for imperfections which might be the locus of failure in the qualification test.

T-220 QUALIFICATION TESTS

Qualification tests shall be performed as required by Pars. T-221 through T-224.

T-221 Barcol Hardness Tests

(*a*) Each prototype vessel shall have at least three Barcol Hardness determinations made along its length on each of its four quadrants. When vessels are longer than 5 feet, one additional set of determinations shall be made for each additional 5 feet or portion thereof. A series of readings shall be taken at each quadrant on smooth surfaces, properly oriented; unusually low, isolated readings shall be discarded.

(*b*) The Barcol Hardness values thus determined shall be recorded in the Manufacturer's Design Report and shall be used as reference values in subsequent Production Tests (see Par. T-440).

T-222 Volumetric Expansion Tests

(*a*) Each prototype vessel shall be subjected to a volumetric expansion test using water or other appropriate liquid.

(*b*) The volume of liquid used to fill the vessel at atmospheric pressure and temperature shall be compared with that required to fill it at the design pressure and the same temperature[1]. Care shall be taken to eliminate air pockets to insure accuracy. The volume of liquid used in each instance shall be determined by any appropriate means, such as a weigh tank, within plus or minus 0.2 percent. The results of this test shall be recorded in the Manufacturer's Design Report and shall subsequently be used in the Quality Control volumetric expansion test.

(*c*) Alternatively, the volumetric expansion may be determined by measuring the overall length of the vessel and its circumference at 5 foot intervals along its length, with a minimum of three such determinations being made, all measurements having an accuracy of at least plus or minus 0.05 percent. These measurements shall be taken with the vessel filled with liquid at atmospheric pressure and at design pressure, both at the same temperature. The measurements thus made shall be recorded in the Manufacturer's Design Report and shall subsequently be used in the Quality Control volumetric expansion test.

T-224 Cyclic Pressure and Bursting Tests

T-224.1 Vessels Intended for Internal Pressure Only At least one prototype vessel, intended for internal pressure service only, shall be subjected to a cyclic pressure test followed by a hydrostatic pressure bursting test[2], as follows:

(*a*) The test fluid shall be water or other appropriate liquid;

(*b*) The temperature of the test fluid shall be 150 F, minimum;

(*c*) The pressure shall be cycled from atmospheric pressure to the design pressure and back 100,000 times[3]; except vessels with liners, whether integral or not, shall be cycled for 10,000 cycles at the minimum design temperature and for 90,000 cycles at the maximum design temperature;

(*d*) The vessel shall then be burst in accordance with the following procedure:

(*1*) The test fluid shall be water or other appropriate liquid, at a temperature of 150 F, minimum;

(*2*) The test pressure shall be applied at a uniform rate so that failure occurs in not less than one minute;

(*3*) The minimum bursting pressure shall be six times the design pressure[4]. However, if the first vessel tested fails within 90 percent of this value, the Manufacturer may burst more vessels which have been subjected to cyclic pressure tests in accordance with subparagraphs (*a*), (*b*) and (*c*). The average bursting pressure of these additional vessels, including that of the first vessel, shall be six times the design pressure and no others shall burst below this value.

T-224.2 Vessels Intended for Both Internal and External Pressure At least one prototype vessel intended for both internal and external pressure service shall be subjected to the following tests:

(*a*) A cyclic pressure test in accordance with the requirements of Par. T-224.1 except that the pressure shall be cycled from the external design pressure to the internal design pressure and back 100,000 times; at the Manufacturer's

[1]The water jacket method described in pamphlet C-1, published by the Compressed Gas Association, Inc., 500 Fifth Ave., New York, N.Y., 10036, may be used.

[2]In the case of vessel designs which have not been previously qualified, it is recommended that a preliminary hydrostatic bursting pressure test in accordance with Par. T-224.1(d) be carried out before the cyclic pressure test of a prototype vessel is conducted.

[3]A lesser number of cycles at a pressure higher than the design pressure, to reduce the time required for the cyclic pressure test, is being considered.

[4]The use of an elastomeric liner to enable attainment of bursting pressure is permissible.

option, the cyclic pressure test may be carried out in two steps, as follows:

(*1*) The pressure shall be cycled from the external design pressure to atmospheric pressure and back 100,000 times;

(*2*) The pressure shall be cycled from atmospheric pressure to the internal design pressure and back 100,000 times;

(*b*) The prototype vessel shall be subjected to an external hydrostatic pressure test, as follows:

(*1*) The test fluid shall be water or other appropriate liquid;

(*2*) The temperature of the test fluid shall be 150F, minimum;

(*3*) The external hydrostatic test pressure shall be twice the external design pressure;

(*4*) The prototype vessel shall show no evidence of buckling;

(*c*) The prototype vessel, after being subjected to the external hydrostatic pressure test required in (*b*) and to the cyclic pressure test required in (*a*) shall then be subjected to a hydrostatic bursting pressure test in accordance with the requirements of Par. T-224.1 (*d*).

T-224.3 Vessels Intended for External Pressure Service Only At least one prototype vessel intended for external pressure service only, shall be tested in accordance with Par. T-224.2 except that the internal design pressure shall be 15 psig.

T-224.4 Vessels Having Bending and Shear Stresses Inherent in Their Design At least one prototype vessel of types having bending and shear stresses inherent in their design shall be subjected to a cyclic pressure test and a hydrostatic bursting pressure test in accordance with Par. T-224.1, Par. T-224.2 or Par. T-224.3, whichever is applicable, except that, in addition, the prototype vessel(s) shall be so loaded as to create the magnitude of bending and shear stresses expected to occur under service conditions (see Par. D-130 (*b*)).

ARTICLE T-3
QUALITY CONTROL TEST REQUIREMENTS

T-300 GENERAL

(*a*) The tests and examinations stipulated in this Article are intended to provide evidence that the Procedure Specification, previously qualified in accordance with Article T-2, is being accurately followed and that no deviations therefrom have been introduced.

(*b*) The results of the tests and examinations stipulated in this Article shall be recorded and kept on file (see Par. G-321 (*f*)). They shall also be made available to the Inspector.

T-301 Requalification of Procedure Specification

If a qualified Procedure Specification has not been utilized for a year or more, it shall be requalified in accordance with the rules of Article T-2 before use in fabricating vessels to be marked with the Code symbol.

T-310 FREQUENCY OF CYCLIC PRESSURE AND BURSTING TESTS

At least one vessel per 1000 duplicate vessels or a minimum of one per year shall be subjected to a cyclic pressure and hydrostatic bursting pressure test in accordance with the requirements of Par. T-224. When less than 1000 vessels of a design are produced in a year, a minimum of one such vessel produced in each year shall be so tested. The vessel to be used for this test shall be selected at random by the qualified Inspector.

T-320 FREQUENCY OF DETERMINATION OF WEIGHT OF RESIN AND FIBERGLASS

At least one determination of the weight of resin and fiberglass shall be made for every 1000 duplicate vessels, with a minimum of at least once a year. The determination shall be made in accordance with Par. T-212 and the weight of the fiberglass shall be within the range specified in the Procedure Specification. The vessel to be used for this test shall be selected at random by the qualified Inspector.

T-330 FREQUENCY OF VOLUMETRIC EXPANSION TESTS

For duplicate vessels, a volumetric expansion test in accordance with the requirements of Par. T-222 shall be performed on one of every 10 vessels and at least once a year. The results of these tests shall be within plus or minus 5 percent of the values recorded in the Test Report.

The vessel to be used for this test shall be selected at random by the qualified Inspector.

T-340 FREQUENCY OF THICKNESS CHECKS

Every vessel shall be visually examined and when there are visual evidences of variation in thickness from that specified in the Manufacturer's Design Report, the area in question shall be explored and its thickness determined as required by Par. T-211. The underthickness deviation shall not exceed 10 percent for a maximum distance of $0.5\sqrt{Rt}$ from the center of the area which is below the thickness specified in the Manufacturer's Design Report, where R is the radius of the shell or head and t is the nominal thickness.

ARTICLE T-4
PRODUCTION TEST REQUIREMENTS

T-400 GENERAL

Each vessel to be marked with the Code symbol shall be subjected to the inspections, examinations and tests stipulated in this Article and shall conform to the specified requirements.

T-410 VISUAL EXAMINATION

Each vessel shall be visually examined, using a suitable light source, to determine whether there are any imperfections which might cause rejection or require removal or repair. This examination shall be carried out both before and after the hydrostatic leakage test required by Par. T-450.

T-411 Acceptance Standards

T-411.1 Design Dimensions Vessels shall be inspected for conformance with dimensions and tolerances shown on the design drawings. Any dimension falling outside the specified limits shall be cause for rejection.

T-411.2 Classification of Imperfections Classification of visual imperfections shall be made as recommended in ASTM D2563-66T.

T-411.3 Imperfections in Noncritical Areas Imperfections in noncritical areas which by nature, content, or frequency do not affect serviceability of the vessel are designated as allowable. The manufacturer shall establish written standards of such acceptable imperfections covering type, size, number, extent allowed and spacing which shall be available to the Inspector.

T-411.4 Inserts, Nuts, Studs and Lugs Inserts, nuts, studs and lugs shall not be damaged in any way, nor coated with laminate material in such a way as to impair function or mechanical fit. Threads in molded-in inserts shall be clean, smooth, free of nicks, tears or other damage. There shall be no laminate materials or flash on the threads. Molded-in threads or cored holes shall be free of visible defects such as chips, cracks, shorts, etc.

T-411.5 Repairable Defects Repairable defects, if any, shall consist of those which can be repaired without affecting the serviceability of the vessel unless prohibited by the Manufacturer's Design Report.

T-412 Repairs of Imperfections

T-412.1 Bag-Molded Vessels and Centrifugally Cast Vessels The Inspector shall first verify that all requirements of Articles I-2 (other than Par. I-210) and I-3 (other than Par. I-310) are met, before considering repair of imperfections.

(*a*) When required by the Manufacturer's Design Report, all cut edges shall be coated with catalyzed resin and cured so that no glass fibers are exposed and all voids are filled.

(*b*) When required by the Manufacturer's Design Report, crevices between joined pieces

shall be filled with catalyzed resin or thixotropic catalyzed resin paste and cured, leaving a relatively smooth surface.

(*c*) If leaks or weeps are detected during the hydrostatic leakage test (see Pars. T-450 and T-451), the vessel shall be dried completely before repairing. Catalyzed resin or catalyzed thixotropic resin paste shall be applied on the surface of the vessel over the area which leaked and forced into the microvoids by moderate air pressure. Initial repair shall be followed as soon as practicable[1] by complete curing. A retest shall be made for leakage.

(*d*) Superficial damage to exterior of vessels subsequent to testing may be repaired by patching with reinforced resin which shall be adequate to restore the original strength. The surface layer of resin shall be ground to a dull finish over the entire area to be repaired and extending a minimum of 2 inches beyond the imperfection. Fiberglass reinforcement may be in form of chopped strand mat, woven fiberglass cloth or woven roving. Where more than one layer of fiberglass cloth or woven roving is to be used, a layer of chopped strand mat shall be placed as alternate layers. The repaired area shall be completely cured to the Barcol Hardness established in the Manufacturer's Design Report (see Pars. T-221 and T-440). Correct fabricating techniques in keeping with the highest standards of the industry shall be employed. The repaired vessel shall be tested as per Par. T-450 or Par. T-461 and a record of the repair shall be noted in the Manufacturer's Design Report.

T-412.2 Filament Wound Vessels The Inspector shall first verify that all requirements of Article I-4 (other than Par. I-410) are met, before considering repair of imperfections.

(*a*) When required by the Manufacturer's Design Report, all cut edges shall be coated with catalyzed resin and cured so that no glass fibers are exposed and all voids are filled.

(*b*) When required by the Manufacturer's Design Report, crevices between joined pieces shall be filled with catalyzed resin or thixotropic catalyzed resin paste and cured, leaving a relatively smooth surface.

(*c*) Liners will be generally used and microvoids capable of leaking will not be a serious problem. Repair of damage shall be done in accordance with Pars. T-412.1(c) and T-412.1(d) with the provision that, after the repair is adequately cured, the vessel shall be pressurized to 1.5 times the design pressure and the repaired area examined for any evidence of crazing or delamination.

T-413 Visual Examination of Repaired Areas

Each repaired area shall be examined visually without the aid of magnification. The repaired area shall have translucency and surface finish comparable to a vessel made in accordance with the Procedure Specification.

T-420 THICKNESS CHECK

Each vessel shall be subjected to a thickness check in accordance with the requirements of Par. T-340.

T-430 VESSEL WEIGHT

Each vessel shall be weighed in accordance with the requirements of Par. T-213. The weight of any vessel shall not be less than 95 percent of that recorded in the Manufacturer's Design Report for the prototype vessels.

T-440 BARCOL HARDNESS TEST

Each vessel shall be subjected to a Barcol Hardness test in accordance with the requirements of Par. T-221. The deviation below the minimum values recorded for the prototype vessels in the Manufacturer's Design Report shall not be more than 5 Barcol units.

T-450 HYDROSTATIC LEAKAGE TEST

Each vessel shall be subjected to a hydrostatic leakage test, using water or other suitable liquid as the test fluid. The test pressure at ambient temperature shall be 1.5 times the design pressure, whether internal or external, and shall be maintained for one minute, after

[1] If polyester is being used, the surface of the repaired area may be covered with cellophane or other suitable nonpermeable film to retard evaporation of monomer.

which the vessel shall be carefully examined for leakage[1] at a pressure at least 2/3 the test pressure. Vessels which show leakage shall be rejected unless they can be repaired in accordance with Par. T-412 and provided they then pass the stipulated hydrostatic test without leakage.

T-450.1 Vessels With Liners Vessels having liners shall be tested with liners in place.

T-450.2 Excessive Hydrostatic Leakage Test Pressure Care shall be taken when pressurizing vessels during hydrostatic tests that the pressure does not exceed 1.5 times the design pressure by more than 10 percent. Exceeding this maximum pressure during the test shall be cause for rejection. To avoid this condition, it is recommended that a properly set safety-relief valve be installed on the vessel or in the line supplying the test fluid to it.

T-460 CONDITIONS UNDER WHICH PENUMATIC LEAKAGE TESTS MAY BE USED

The pneumatic tests described herein may be used in lieu of the hydrostatic leakage test prescribed in Par. T-450 only if either of the conditions in Par. T-460.1 or T-460.2 apply.

NOTE: Air or gas is hazardous as a testing medium It is, therefore, recommended that special precautions be taken when air or gas is used for test purposes.

T-460.1 When Vessels Cannot Be Safely Filled With Water Pneumatic testing may be used for vessels which are so designed and/or supported that they cannot be safely filled with water. The test of such vessels may be made with the vessels partially filled with water, if desired.

T-460.2 When Traces of Test Fluid Cannot Be Tolerated Pneumatic testing may be used for vessels, not readily dried, which are to be used in services where traces of testing liquid cannot be tolerated.

T-461 Required Pneumatic Test Pressure and Holding Time

(*a*) The test pressure at ambient temperature shall be 1.25 times the design pressure and shall be maintained for at least one minute. The pressure in the vessel shall be gradually increased to not more than one-half the test pressure after which the pressure shall be increased in steps of approximately 1/10 the test pressure until the required test pressure has been reached.

(*b*) After the test pressure has been maintained for at least one minute, it shall be reduced to 3/4 of the design pressure and maintained at that pressure for sufficient time to permit examination for leakage of the entire surface of the vessel and its attachments by means of soapsuds applied thereto. At the Manufacturer's option, leakage determination may be made by testing the vessels with air under water.

(*c*) When the test medium is air or gas instead of water or other liquid, the requirements of Par. T-450 as to liners, repair of leaks, excessive test pressure and rejection shall also apply.

[1] It is recommended that before examination for leakage is begun, the test pressure be lowered to a value equal to the design pressure.

ARTICLE T-5
HYDROSTATIC AND PNEUMATIC TESTING PROCEDURES AND EQUIPMENT

T-500 PROVISION OF VENTS AT HIGH POINTS

Vents shall be provided at all high points of vessels in the position being tested hydrostatically to purge possible air pockets while the vessel is being filled.

T-501 Examination of Test Equipment

Before applying pressure, the test equipment shall be examined to see that it is tight and that all low pressure filling lines and other appurtenances that should not be subjected to the test pressure have been disconnected or isolated by valves or other suitable means.

T-502 Rate of Applying Leakage Test Pressure[1]

The pressure in the vessel shall be gradually increased to not more than ½ the test pressure, after which the pressure shall be increased in steps of $^1/_{10}$ of the test pressure until the required test pressure has been reached.

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[1] This rule does not apply to vessels pressurized behind barricades or tested with air under water.

T-510 TYPE AND NUMBER OF PRESSURE TEST GAGES

Pressure test gages used in testing vessels shall be indicating pressure gages. If the indicating gage is not readily visible to the operator controlling the pressure being applied, an additional indicating gage shall be provided where it will be visible to the operator throughout the duration of the test. It is recommended that a recording gage be used in addition to the indicating gage.

T-511 Pressure Range of Test Gages

Indicating pressure gages used in testing shall preferably have dials graduated over a range about double the intended maximum test pressure but in no case shall the range be less than 1½ nor more than 4 times that pressure.

T-520 CALIBRATION OF TEST GAGES

All gages shall be calibrated against a standard dead-weight tester or a calibrated master gage at least once every six months or at any time there is reason to believe that they are in error.

PART I
RULES GOVERNING INSPECTION

ARTICLE I-1
GENERAL

I-100 SCOPE

The inspection and examination of all pressure vessels to be marked with the Code symbol shall conform to the general requirements set forth in this Article. The special requirements for vessels made by the Bag-Molding, the Centrifugal-Casting or the Filament-Winding process are given in Articles I-2,I-3 and I-4, respectively, of this Part.

I-101 Manufacturer's Responsibility

The Manufacturer who completes any vessel to be stamped with the Code symbol (see Par. S-110) has the responsibility of complying with all the requirements of the Code, and through proper certification, of assuring that any work done by others also complies with all requirements of the Code.

I-110 QUALIFICATION OF INSPECTORS

The inspection required by this Division shall by carried out by an inspector employed by a State or Municipality of the United States, a Canadian Province or by an inspector regularly employed by an insurance company authorized to write boiler and pressure vessel insurance. These inspectors shall have been qualified by written examination under the rules of any State of the United States or Province of Canada which has adopted the Code. An inspector continuously employed by a company for making inspections of pressure vessels to be used exclusively by that company and not for resale may be accepted as a qualified inspector. The Inspector shall not be in the employ of the manufacturer. All reference throughout this Section to "Inspector" means "qualified inspector" as defined in this paragraph.

I-120 ACCESS FOR INSPECTOR

The Manufacturer of the vessel shall arrange for the Inspector to have free access to such parts of all plants as are concerned with the supply or manufacture of materials for the vessel, when so requested. The Inspector shall be permitted free access, at all times while work on the vessel is being performed, to all parts of the Manufacturer's shop that concern the construction of the vessel and to the site of field-erected vessels during the period of assembly and testing of the vessel. The Manufacturer shall keep the Inspector informed of the progress of the work and shall notify him, reasonably in advance, when vessels will be ready for any required tests or inspections.

I-130 INSPECTOR'S DUTY

I-130.1 Inspector's Duty Relative to Qualification Tests of Prototype Vessels The Inspector shall verify the cyclic pressure tests and witness the hydrostatic bursting pressure tests (see Par. T-224) of the prototype vessels by means of which the vessel design and the fabrication procedure are qualified.

I-130.2 Inspector's Duty Relative to the Manufacturer's Design Report The Inspector shall determine that the Manufacturer's Design Report is on file and shall examine it to verify that:

(*a*) The vessel design conforms to the design drawings in all respects;

(*b*) The materials being used and the fabrication procedures being employed are in strict accordance with the requirements of the Procedure Specification;

(*c*) The Quality Control Specification is being followed routinely and that the tests stipulated by it confirm that the Procedure Specification requirements are being met;

(*d*) The vessel design, as demonstrated by the Test Report, is adequate to safely withstand the specified service conditions which are to be marked on the completed vessel.

I-130.3 Inspector's Duty Relative to Specific Vessels The Inspector of vessels to be marked with the Code symbol has the duty of making all required inspections plus such other inspections necessary to assure himself that all requirements of this Section have been met.

I-130.4 Inspector's Duty Relative to Multiple Duplicate Vessels When multiple duplicate pressure vessel fabrication makes it impracticable for the Inspector to personally check each item of inspection and test as required in Par. I-130.3, the Manufacturer, in collaboration with the qualified Inspector, shall prepare an inspection procedure setting forth in complete detail the methods by which the requirements of the Code will be maintained. This procedure shall be submitted to and shall have received the approval of the inspection agency. It then shall be submitted by the inspection agency to the appropriate authority, under which the Inspector is commissioned, for written approval. This inspection procedure shall be used in the plant of the named Manufacturer by the inspection agency submitting it and shall be carried out by a qualified Inspector in the employ of that inspection agency, unless modified by agreement between the appropriate authority and the inspection agency.

I-140 INSPECTION OF MATERIAL

(*a*) The Inspector shall assure himself that all materials used in the construction of the vessel comply in all respects with the requirements of this Section and the Design Specification.

(*b*) All parts to be incorporated into the completed pressure vessel, whether or not produced by the Manufacturer, shall be inspected before fabrication for the purpose of detecting, as far as possible, any imperfections which would affect the safety of the vessel.

I-150 INSPECTION DURING FABRICATION

(*a*) Except as provided for in Par. I-130.4, the Inspector shall make inspections of each pressure vessel at such stages of construction as are required plus such other inspections as he deems are necessary to assure himself that fabrication is in accordance with Code requirements.

(*b*) When conditions permit entry into the vessel, as complete an examination as possible shall be made before final closure.

(*c*) It is recommended that an inspection be made at the time of the hydrostatic leakage test or its permissible equivalent.

ARTICLE I-2
SPECIAL INSPECTION REQUIREMENTS FOR BAG-MOLDED VESSELS

I-200 CHECK OF BAG-MOLDING PROCEDURE SPECIFICATION QUALIFICATION

The Inspector shall examine the Manufacturer's Procedure Specification and shall determine that the procedure for the bag-molding process has been properly qualified as required by Part Q.

I-201 Additional Tests

At his discretion, the Inspector shall have the right to call for and witness additional tests of the bag-molding procedure.

I-202 Check of Glass Weight

The Inspector shall verify that the glass weight of preforms and of side wall mats conforms to the requirements of Pars. F-200 and F-320.

I-203 Check of Form of Reinforcement

The Inspector shall verify that the form of glass reinforcement used in the shell and in the heads conforms to requirements of Par. F-210.

I-204 Check of Fabrication Procedures

The Inspector shall verify that the processing pressure, processing temperatures during layup and pumping procedures correspond to those stipulated in the qualified Procedure Specification.

I-205 Check of Cure

(*a*) The Inspector shall satisfy himself by suitable hardness tests or by other means that the bag-molded composite structure has been properly cured.

(*b*) A post cure, after removal of the vessel from the mold, if required, shall be for the time and temperature specified in the qualified Procedure Specification (see Form Q-106).

I-206 Check of Uniformity of Heating for Cure of Vessel

The Inspector may require the Manufacturer to demonstrate that operation of the heating system provides uniform heating over the entire surface of the vessel. The temperature variation shall not exceed plus or minus 10 F from the specified cure temperature in the qualified Procedure Specification (see Form Q-106).

I-210 VISUAL INSPECTION

Where possible, the Inspector shall inspect both the inside and outside of the bag-molded pressure vessel. He shall examine the vessel for the following defects: indentations, cracks, porosity, air bubbles, exposed fibers, lack of resin, excess resin, thin areas, wrinkling,

uniformity of seal surface and delamination (see Pars. T-411, T-412 and T-413).

I-210.1 Required Translucency The pressure vessel wall shall be sufficiently translucent, so that "candling" will assist in examination for presence of knotted fibers, inclusions, etc.

I-215 Tests and Retests

The physical property tests of specimens of material, hydrostatic or pneumatic leakage tests, cyclic pressure and hydrostatic bursting pressure tests and any permitted retests, all stipulated in Part T-5, shall be witnessed by the Inspector.

ARTICLE I-3
SPECIAL INSPECTION REQUIREMENTS FOR CENTRIFUGALLY CAST VESSELS

I-300 CHECK OF CENTRIFUGAL-CASTING PROCEDURE SPECIFICATION QUALIFICATION

The Inspector shall examine the Manufacturer's Procedure Specification and shall determine that the procedure for the centrifugal-casting process has been properly qualified as required by Part Q.

I-301 Additional Tests

At his discretion, the Inspector shall have the right to call for and witness additional tests of the centrifugal-casting procedure.

I-302 Check of Glass Weight

The Inspector shall verify that the glass weight of the composite of fiberglass and resin conforms to requirements of Pars. F-300 and F-320.

I-303 Check of Form of Reinforcement

The Inspector shall verify that the filament length of the chopped strand is not less than 1 in. as required by Par. F-300.

I-304 Check of Fabrication Procedures

The Inspector shall verify that the speed of mandrel rotation and the processing temperature of the mandrel during buildup of the wall correspond to those stipulated in the qualified Procedure Specification (see Form Q-106).

I-305 Check of Cure

(*a*) The Inspector shall satisfy himself by suitable hardness tests, or by other means, that the centrifugally cast cylinder has been properly cured.

(*b*) A post cure, after removal of the vessel from the mandrel, if required, shall be for the time and temperature specified in the qualified Procedure Specification (see Form Q-106).

I-306 Check of Uniformity of Heating for the Cure of the Vessel

The Inspector may require the Manufacturer to demonstrate that the mandrel heating system provides uniform heating of the entire surface of the vessel. The temperature variation shall not exceed plus or minus 10 F from the specified cure temperature in the qualified Procedure Specification (see Form Q-106).

I-307 Check of Attachment of Heads to Cylinder

I-307.1 Heads Attached by Adhesive Bonding The Inspector shall verify that the adhesive used, the preparation of the surfaces to be joined and

the application of the adhesive conform to the Procedure Specification for Qualification of Adhesive Bonding (Form Q-115).

I-307.2 Cylinders Centrifugally Cast Into or Onto Heads If the alternative procedure of centrifugally casting cylinders directly into or onto the head skirt is used, the Inspector shall verify that it follows the qualified fabrication procedure for such attachment.

I-310 VISUAL INSPECTION

Where possible, the Inspector shall inspect both the inside and outside of the centrifugally cast cylinder and the bag- or matched-die-molded heads before assembly. He shall examine the vessel for the following defects: surface cracks or checking, lack of resin, excess resin, thin areas, air bubbles, exposed fibers, wrinkling, uniformity of seal surface and delaminations (see Pars. T-411, T-412 and T-413).

I-310.1 Required Translucency The pressure vessel wall and the heads shall be sufficiently translucent, so that "candling" will assist in examination of the completed vessel.

I-315 Tests and Retests

The physical property tests of specimens of material, hydrostatic or pneumatic leakage tests, cyclic pressure and hydrostatic bursting pressure tests and any permitted retests, all stipulated in Part T-5, shall be witnessed by the Inspector.

ARTICLE I-4
SPECIAL INSPECTION REQUIREMENTS FOR FILAMENT-WOUND VESSELS

I-400 CHECK OF FILAMENT-WINDING PROCEDURE SPECIFICATION QUALIFICATION

The Inspector shall examine the Manufacturer's Procedure Specification and shall determine that the procedure for the filament-winding process has been properly qualified as required by Part Q.

I-401 Additional Tests

At his discretion, the Inspector shall have the right to call for and witness additional tests of the filament-winding procedure.

I-402 Check of Glass Weight

The Inspector shall verify that the glass weight, of the combined fiberglass filaments and resin conforms to requirements of Pars. T-400 and T-320.

I-403 Check of Materials

The Inspector shall verify that the fiberglass, resin and curing agent being used are as described in the Procedure Specification (see Par. Q-107).

I-404 Check of Fabrication Procedures

The Inspector shall verify that the speed of winding, uniformity of tension, and adherence to the predetermined patterns of the qualified Procedure Specification (see Form Q-107) are closely followed.

I-405 Check of Cure

(*a*) The Inspector shall satisfy himself by suitable hardness tests, or by other means, that the filament-wound structure has been properly cured.

(*b*) A post cure, if required, after removal of the mandrel, shall be for the time and temperature specified in the qualified Procedure Specification (see Form Q-107).

I-406 Check of Uniformity of Heating for the Cure of the Vessel

The Inspector may require the Manufacturer to demonstrate that operation of the heating system provides uniform heating over the entire surface of the vessel. The temperature variation shall not exceed plus or minus 10 F from the specified cure temperature in the qualified Procedure Specification (see Form Q-107).

I-410 VISUAL INSPECTION

Where possible, the Inspector shall inspect both the inside and outside of the filament-wound

pressure vessel. He shall examine the vessel for the following defects: indentations, cracks, porosity, air bubbles, exposed fibers, lack of resin, excess resin, thinned areas, wrinkling, pattern deviations, and delaminations (see Pars. T-411, T-412 and T-413).

I-410.1 Required Translucency The pressure vessel wall shall be sufficiently translucent, so that "candling" will permit examination for winding pattern uniformity, presence of knotted fibers, inclusions, etc.

I-415 Tests and Retests

The physical property tests of specimens of material, hydrostatic or pneumatic leakage tests, cyclic pressure and hydrostatic bursting pressure tests, and any permitted retests, all stipulated in Part T-5, shall be witnessed by the Inspector.

PART S
MARKING, STAMPING AND REPORTS

ARTICLE S-1
CONTENTS, METHODS AND MEANS OF MARKING

S-100 REQUIRED MARKING FOR VESSELS

Each pressure vessel shall be marked, by means other than stamping directly on the vessel (see Par. S-130), with the following:

(*a*) The official Code symbol as shown in Fig. S-100.1;

(*b*) The type of fabricating process indicated by the letters BM, CC or FW;

(*c*) The Manufacturer's name;

(*d*) The design pressure____psi at ______ F;

(*e*) The minimum permissible temperature (not less than minus 65 F);

(*f*) The Manufacturer's serial number;

(*g*) The year built.

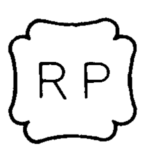


FIG. S-100.1 OFFICIAL SYMBOL FOR MARK TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD

S-101 Methods of Marking Vessels with Two or More Independent Chambers

Either of the following arrangements may be used in marking vessels having two or more independent pressure chambers designed for the same or different operating conditions. Each detachable chamber shall be marked so as to identify it positively with the combined unit.

S-101.1 If Markings Are Grouped in One Location The markings may be grouped in one location on the vessel, provided they are arranged so as to indicate clearly the data applicable to each chamber including the maximum differential pressure for the common elements, when this pressure is less than the higher pressure in the adjacent chambers.

S-101.2 If Each Independent Chamber is Marked The complete required marking may be applied to each independent pressure chamber, provided additional marking, such as stock space, jacket, tubes, or channel box, is used to indicate clearly to which chamber the data apply.

S-110 APPLICATION OF STAMP[1] TO VESSEL

The Manufacturer who completes the fabrication of the vessel shall have a valid certificate of authorization for the use of the Code RP symbol. Except when the Code symbol is to be molded in, the Code symbol shall be applied by the manufacturer only with the approval of the Inspector after the hydrostatic or pneumatic leakage test has been satisfactorily made and all other required inspection and testing have been satisfactorily completed. Such application of the Code symbol together with final certification in accordance with the rules of this Section shall confirm that all applicable Code requirements have been fulfilled.

S-120 PART MARKING

Parts of pressure vessels for which partial data reports are required in Par. S-301 shall be marked as specified in Par. S-100 by the parts manufacturer and, in addition, the word PART shall be applied under the Code symbol. This requirement does not apply to such items as handhole covers, manhole covers and accessories.

S-130 NAMEPLATE

The markings required in Par. S-100 shall be applied to a separate nameplate permanently attached to the vessel by suitable means. The marking shall not be stamped directly on the vessel.

[1] Wherever the word "stamp" or "stamping", referring to the Code symbol to be applied to the vessel (but not to safety or safety-relief devices), appears in this document, it may be construed to mean marking the vessel with the Code RP symbol by means other than a steel stamp (see Pars. S-130 and S-131).

S-131 Stamping and Attachment of Nameplates or Molded-in Printed Labels

(*a*) The Code symbol and the Manufacturer's serial number shall be stamped on the nameplate with "low stress" stamps, but the other required data may be stamped, etched, cast or impressed thereon. Alternatively, the other data may be printed or engraved on a suitable material and then be molded as an integral part of the vessel to serve as a nameplate. The arrangement of the data shall be substantially as shown in Fig. S-132.1.

(*b*) The required data on a nameplate or a molded-in printed or engraved label shall be in characters not less than 5/16 in. high.

(*c*) Required nameplates shall be permanently attached to the vessel in some conspicuous place, either by use of a surface mat or by molding in as an integral part of the vessel or by some other suitable means.

(*d*) The Manufacturer shall see that the nameplate with the correct marking has been applied to the proper vessel and the Inspector shall satisfy himself that this has been done.

S-132 Stamping of Nameplates

The stamping shall be arranged as shown in Fig. S-132.1 when space permits.

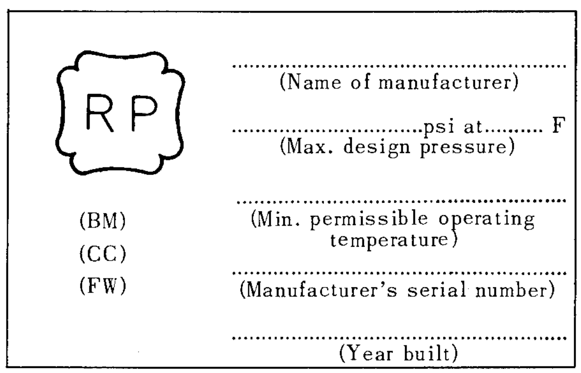


FIG. S-132.1 FORM OF STAMPING

ARTICLE S-2
USE OF CODE STAMPS

S-200 CODE STAMPS BEARING OFFICIAL SYMBOL

Authorization to use the stamp bearing the official Code symbol shown in Fig. S-100.1 will be granted by the Society pursuant to the provisions of Pars. S-201, S-202 and S-203.

S-201 Application for Code Stamp

Any manufacturer of vessels classified under Section X may apply to the Boiler and Pressure Vessel Committee of the Society, in writing, upon forms issued by the Society for the loan of a Code stamp and authorization to use it. Each applicant shall agree, if authorization to use the stamp is granted, that the stamp is at all times the property of the Society, that it will be used according to the rules and regulations of this Section and that the stamp will be promptly returned to the Society upon demand, or in case the applicant discontinues the manufacture of such vessels, or in case the Certificate of Authorization issued to such applicant has expired and no new certificate has been issued. The holder of a Code stamp shall not permit any others to use the stamp loaned to him.

S-202 Authorization to Use Stamp

Authorization to use the stamp may be granted or withheld by the Society in its absolute discretion. If authorization is given and the proper administrative fee is paid, a Certificate of Authorization evidencing permission to use such a symbol, expiring on the triennial anniversary date thereafter, will be forwarded to the applicant. Each such certificate will be signed by the Chairman and Secretary, or other duly authorized officer or officers, of the Boiler and Pressure Vessel Committee. Six (6) months prior to the date of expiration of any such certificate, the applicant shall apply for a renewal of such authorization and the issuance of a new certificate. The Society reserves the absolute right to cancel or refuse to renew such authorization, returning fees paid for the pro-rated unexpired term.

S-203 Regulations Concerning Issuance and Use of Stamps

The Boiler and Pressure Vessel Committee may, at any time and from time to time, make such regulations concerning the issuance and use of such stamps as seems appropriate and all such regulations shall become binding upon the holders of valid Certificates of Authorization.

S-204 Obtaining of Stamps

All stamps for applying the Code symbol shall be obtained from the Society.

ARTICLE S-3
REPORT FORMS

S-300 MANUFACTURER'S DATA REPORTS

A Manufacturer's Data Report shall be filled out on Form RP-1 (a sample Form RP-1 is given at the end of this Section) by the Manufacturer and shall be signed by the Manufacturer and the Inspector for each pressure vessel to be stamped with the Code symbol.

S-301 Partial Data Reports

Partial Data Reports for those parts of a pressure vessel requiring inspection under this Section, which are furnished by other than the shop of the Manufacturer responsible for the completed vessel, shall be executed by the parts manufacturer and the Inspector in his shop, in accordance with the Code requirements, and shall be forwarded, in duplicate, to the manufacturer of the finished vessel. These Partial Data Reports, together with his own inspection, shall be the final Inspector's authority to approve and witness the application of a Code symbol to the vessel (see Par. S-110). A sample Data Report, Form RP-2, is given at the end of this Section.

NON-MANDATORY APPENDIX 1 SUGGESTED METHODS OF PRELIMINARY DESIGN

ARTICLE 1-1 GENERAL

I-100 SCOPE

(*a*) Section X does not provide mandatory rules for the design of fiberglass-reinforced plastic pressure vessels. However, to assist the designer in establishing thicknesses of vessels, the design of which must be qualified by tests to destruction of prototype vessels (see Article T-2), this Appendix gives suggested methods of arriving at tentative thicknesses for the principal pressure parts. Additionally, this Appendix indicates the types of end closures which have been found satisfactory when constructed of or attached to fiberglass-reinforced plastic pressure vessels.

(*b*) Design procedures other than given in this Appendix may be used at the Manufacturer's option.

I-101 Cautions to be Used in Design

Since fiberglass-reinforced plastic laminates may fail when subjected to cyclic bending stresses, the designer is cautioned to avoid design details in which bending stresses will be developed by internal or external pressure or other loadings.

ARTICLE 1-2
SHELLS OF REVOLUTION UNDER INTERNAL PRESSURE

I-200 GENERAL

The tentative thicknesses and design pressures of cylindrical and spherical shells under internal pressure may be estimated by means of the formulas given in this Article.

1-200.1 Nomenclature The symbols used in this Article are defined as follows:

- α = filament helix angle for filament-wound vessels, measured relative to a line on the shell surface parallel to the axial center line, degrees
- D = inside diameter of a head skirt or inside length of the major axis of an ellipsoidal head, in.
- N_α = required number of layers of laminates in which the filaments are oriented in the direction of the helix angle, α
- N_H = required number of layers of laminates in which the filaments are oriented in the hoop direction
- P = design pressure, psi
- R = inside radius of cylinder or sphere or inside spherical or crown radius of a hemispherical head
- S = tentative design stress in a circumferential direction in the wall of a bag-molded or centrifugally cast cylinder or sphere. May be approximated by dividing the stress at burst of a similarly constructed pressure vessel by 6
- S_α = allowable design stress of the helix-oriented filaments, psi (Normally less than the allowable design stress for hoop-oriented filaments due to unavoidable cross-overs, discontinuities, etc. With 400,000 psi Type E glass filaments, using the 1/6 design factor required by this Section and applying an efficiency of 70 percent, S_α would be 47,000 psi.)
- S_H = allowable design stress in hoop-oriented filaments, psi (With 400,000 psi Type E glass filaments, using the 1/6 design factor required by this Section and applying an efficiency of 90 percent, S_H would be 60,000 psi.)
- t = required thickness, in.
- t_α = thickness of the required number of layers of laminates in which the filaments are oriented in the plus and minus α direction, in.
- t_H = thickness of the required number of layers of laminates in the hoop direction, in.
- t'_α = equivalent thickness of the helix-oriented filaments per unit of width of a layer of bands at plus and minus α, in.
- t'_H = equivalent thickness of the hoop-oriented filaments per unit of width of a layer composed of two band thicknesses, in. (For

a typical band density of 144 ECG – 135 ends[1] per in., $t_H' = 144 \times 204 \times 2\ (.000375'')^2 \times \pi/4 \div 1 = 0.0065$ in.)

V_α = volume fraction of helix-oriented filaments (This may range from about 0.45 for low (small) helix angles wound at low tension with high viscosity resin on large diameter mandrels to about 0.65 for high (say, above 25 degrees) helix angles wound at high tension with low viscosity resin on small diameter mandrels

1-201 Bag-Molded and Centrifugally Cast Shells

1-201.1 Cylindrical Shells The thicknesses of bag-molded and centrifugally cast cylindrical shells may be estimated by the following formulas[2]:

$$t = \frac{PR}{S} \quad \text{or} \quad P = \frac{St}{R}$$

1-201.2 Spherical Shells The thicknesses of bag-molded and centrifugally cast spherical shells may be estimated by the following formulas[2]:

$$t = \frac{PR}{2S} \quad \text{or} \quad P = \frac{2St}{R}$$

1-202 Filament-Wound Shells

1-202.1 Cylindrical Shells The thicknesses of filament-wound cylindrical shells may be estimated by the following formulas:

$$t = t_H + t_\alpha$$

where

$$t_H = \frac{N_H + t_H'}{V_\alpha}$$

$$N_H = \frac{P \times R}{t_H' \times S_H}\left(1 - \frac{\tan^2 \alpha}{2}\right)$$

and

$$t_\alpha = \frac{N_\alpha \times t_\alpha'}{V_\alpha}$$

$$N_\alpha = \frac{P \times R}{2 \times t_\alpha' \times S_\alpha \cos^2 \alpha}$$

NOTE: The above formulas are based on the netting analysis which assumes that the resin carries no load. This is a workably correct assumption of the actual condition in filament-wound composites, highly stressed in tension. For more rigorous analyses, refer to:

(1) "Structural Behavior of Composite Materials", 1964 NASA Contract 7-215, S. Tsai, available from Office of Technical Services, Dept. of Commerce, Washington, D.C. 20230.

(2) Journal of Composite Materials, Technical Publishing Co., Stamford, Conn. 06902.

1-202.2 Spherical Shells

(In course of development)

I-210 DIE-FORMED HEADS, PRESSURE ON CONCAVE SIDE

The thickness at the thinnest point of an ellipsoidal or hemispherical head under pressure on the concave side (plus heads) may be estimated by the formulas in Par. 1-210.1 or 1-210.2.

1-210.1 Ellipsoidal Heads The thickness and the design pressure of a 1½:1 ratio head may be estimated by the following formulas[2]:

$$t = \frac{PR}{S} \quad \text{or} \quad P = \frac{St}{R}$$

1-210.2 Hemispherical Heads The thickness and the design pressure of a hemispherical head, in which t does not exceed $0.356R$ or P does not exceed $0.665S$, may be estimated by the following formulas[2]:

$$t = \frac{PR}{2S} \quad \text{or} \quad P = \frac{2St}{R}$$

[1] An "ECG – 135 end" consists of 204 Type E glass composition Continuous filaments of the G diameter (approximately 0.000375 in.).

[2] The formulas in this Article are for isotropic materials only. Any deviation from such materials will require modifications of the formulas.

ARTICLE 1-3
SHELLS OF REVOLUTION UNDER EXTERNAL PRESSURE

Note: Jacketed vessels are excluded from this Section.

1-300 GENERAL REQUIREMENTS

No firm rules or formulas can be given for vessels under external pressure. However, the following must be considered in the design of the vessel:

(*a*) The low modulus of elasticity of the material;

(*b*) The fact that the material is not isotropic;

(*c*) The orientation of filaments in filament-wound vessels;

(*d*) Lack of uniformity in centrifugal-castings and the different distributions and concentrations of glass fibers attainable in centrifugal-castings, some of which are not suitable for external pressure.

ARTICLE 1-4
REINFORCEMENT OF OPENINGS IN VESSELS

1-400 GENERAL REQUIREMENTS

(*a*) All openings in fiberglass-reinforced plastic pressure vessels should have additional reinforcement in the form of mats, pads, etc.

(*b*) Opening reinforcement should be provided in amount and distribution such that the area requirements for adequate reinforcement are satisfied for all planes through the center of the opening and normal to the vessel surface. For a circular opening in a cylindrical shell, the plane containing the axis of the shell is the plane of greatest loading due to pressure.

1-410 REINFORCEMENT FOR INTERNAL PRESSURE

Suggested methods of predetermining the required reinforcement are given in Pars. 1-411 through 1-415.

1-411 Required Cross-Sectional Area of Reinforcement

The total cross-sectional area of reinforcement, A, required in any given plane for a vessel under internal pressure should be not less than:

$$A = d \times t_r$$

where d = the diameter in the given plane of the finished opening in the reinforced plastic structure

t_r = the estimated thickness of a seamless shell or head computed in accordance with Article 1-2

1-412 Limits of Reinforcement

The limits of wall thickness reinforcement, measured parallel to the vessel wall, should be at a distance on each side of the axis of the opening equal to the diameter of the opening in the reinforced plastic structure.

1-413 Available Reinforcement in Wall

Extra thickness in the vessel wall over and above the thickness, estimated to be required for a shell in accordance with Article 1-2, may be considered as reinforcement. The area in the vessel wall available as reinforcement is given by the formula:

$$A_1 = (t - t_r)\, d$$

where A_1 = area in excess thickness in the vessel wall available for reinforcement, square inches

t = actual thickness of the reinforced plastic wall, in.

t_r = required thickness of shell, in.

d = diameter of the opening in the reinforced plastic wall, in.

1-414 Adjustment for Lower Strength or Lower Modulus Reinforcement Material

(*a*) Material used for reinforcement, if of lower strength than the material in the vessel wall, shall have its area increased in inverse proportion to the ratio of the minimum strength values of the two materials (see Par. M-130) to compensate for

its lower strength. The strain should be compatible with the material having the lower modulus of elasticity.

(*b*) Where reinforcement material is attached to the vessel wall by an adhesive-bonding rather than being cured integral with the vessel, the adhesive-bonded area shall be sufficient to develop the full tensile strength of the element of reinforcement.

1-415 Reinforcement of Multiple Openings

(*a*) When two adjacent openings are spaced less than two times their average diameter, so that their limits of reinforcement overlap, the two openings should be reinforced as required by Par. D-510 with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for the separate openings. No portion of the cross-section should be considered as applying to more than one opening or be evaluated more than once in the combined area.

(*b*) Any change in which the size of openings is increased openings or in which the spacing of openings is decreased shall be considered a change in the design of the vessel, which, so modified, shall be requalified.

ARTICLE 1-5
ATTACHMENTS AND SUPPORTS

1-500 GENERAL

(*a*) Attachments and supports invariably impose localized stresses in tension, torsion, shear, bending or compression at their point or line of contact with the shell of a pressure vessel.

(*b*) Because of the low modulus of elasticity and shearing strengths of fiberglass-resin structures, they are especially vulnerable to localized compressive flexural buckling, torsion and shear stresses.

(*c*) Hence the designer should use special care to avoid as much as possible any unnecessary attachments and assure that supports apply the least possible restraint to the pressure vessel (see Article D-9).

1-510 ATTACHMENTS

The practice of using a pressure vessel as a structural member to support related auxiliary equipment, piping, etc., should be avoided.

1-511 Attachments Requiring Reinforcement

Where a nozzle or the vessel wall must be used for attachments, local reinforcement should be provided to distribute the consequent applied stresses to provide the required safety. This reinforcement should be such as to minimize the total resulting stress. The extra material of the reinforcement should be smoothly blended into the surrounding area.

1-520 SUPPORTS

Exact rules for the design of supports are not given here due to the very large range of essential variables that must be considered. Details should conform to good structural practice and be carefully analyzed for stresses.

1-521 Avoidance of Direct Contact with Metal Supports

Direct contact of metal supports with highly stressed areas of a fiberglass plastic pressure vessel should be avoided, as dangerously high, local, flexural and shearing stresses may be generated in the wall of the vessel when it expands or contracts upon changes in its pressure.

1-522 Supports for Horizontal Vessels

(*a*) When horizontal vessels must be supported by a saddle-type support (see Fig. 1-522.1), the vessel wall thickness may be increased at the point of contact, blending this thicker section smoothly and gradually into the more highly stressed adjacent area. This increased thickness should extend uniformly around the complete circumference. The vessel should preferably be isolated from rigid supporting saddles by a very low-modulus-of-elasticity-cushioning material. If two or more such saddles are required for a long vessel, special provision for avoiding restraint

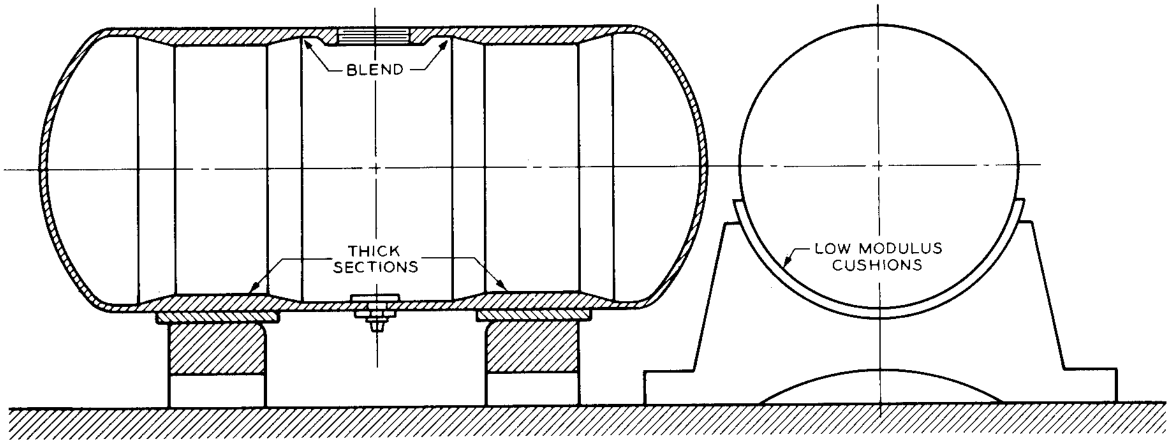


FIG. 1-522.1 SADDLE TYPE SUPPORTS

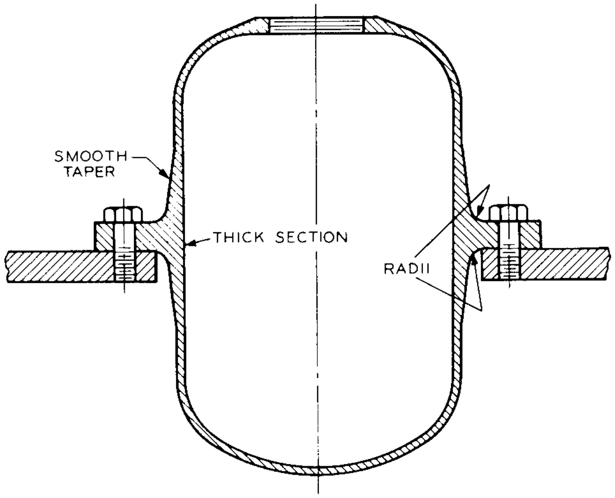


FIG. 1-523.1 RING OR FLANGE SUPPORT

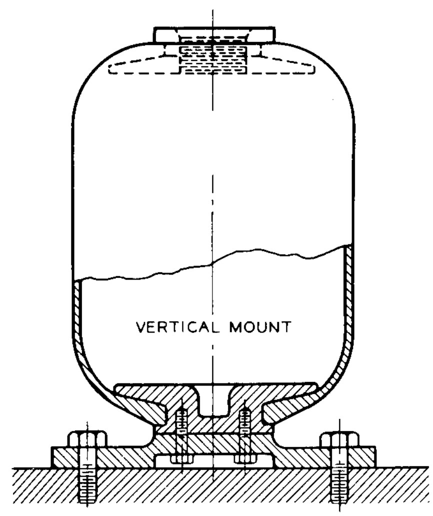


FIG. 1-524.1 METAL ATTACHMENT IN VESSEL END

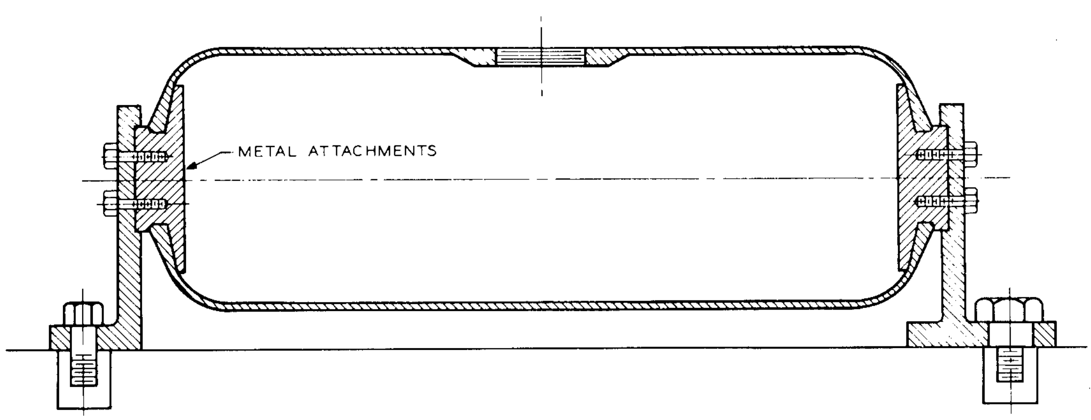


FIG. 1-524.2 METAL ATTACHMENTS IN THICKENED ENDS

of sliding due to longitudinal expansion and contraction may be required at all except one of the supports.

(*b*) Increasing the bearing area of the supports so that the weight per square foot imposed by the vessel on the supports is low may eliminate the need to reinforce the vessel wall.

1-523 Vertical Vessels Supported by a Ring or Flange

When a ring- or flange-type support is used to support a vertical vessel, the vessel wall at the base of the ring or flange should be blended in gradually with a smooth taper to a thickened section and generous fillet radius at the transition to the flange section itself (see Fig. 1-523.1).

1-524 Vertical Vessels Supported by Metal Attachment in Vessel End

Vertical vessels may often be supported by metal attachments embedded in thickened material at the axial center-line of the heads (see Figs. 1-524.1 and 1-524.2)

1-525 Provision for External Forces

Due consideration must be given to wind, earthquake, snow and any other external forces when designing supports.

NON-MANDATORY APPENDIX 2 CAPACITY CONVERSIONS FOR SAFETY VALVES

2-100 REQUIREMENTS FOR CAPACITY CONVERSIONS

(a) The capacity of a safety or relief valve in terms of a gas or vapor other than the medium for which the valve was officially rated may be determined by application of the following formulas:[1]

For Steam:

$$W_s = 51.5KAP$$

For Air:

$$W_a = CKAP\sqrt{\frac{M}{T}}$$

$C = 356$
$M = 28.97$
$T = 520$ when W_a is the rated capacity

For any Gas or Vapor:

$$W = CKAP\sqrt{\frac{M}{T}}$$

where
W_s = rated capacity, lb of steam per hour
W_a = rated capacity, converted to lb of air per hour at 60 F, inlet temperature
W = flow of any gas or vapor, lb per hour
C = constant for gas or vapor which is a function of the ratio of specific heats, $k = c_p/c_v$ (see Fig. 2-100.1)
K = coefficient of discharge (see Pars. R-421 and R-423)
A = actual discharge area of the safety valve, square in.
P = (set pressure × 1.10) plus atmospheric pressure, psia
M = molecular weight
T = absolute temperature at inlet (degrees F plus 460)

These formulas may also be used when the required flow of any gas or vapor is known and it is necessary to compute the rated capacity of steam or air.

(b) Molecular weights of some of the common gases and vapors are given in Table 2-100.1.

(c) For hydrocarbon vapors, where the actual value of k is not known, the conservative value, $k = 1.001$ has been commonly used and the formula becomes,

$$W = 315\ KAP\sqrt{\frac{M}{T}}$$

---

[1] Knowing the official rating capacity of a safety valve which is stamped on the valve, it is possible to determine the overall value of KA in either of the following formulas in cases where the value of these individual terms is not known:

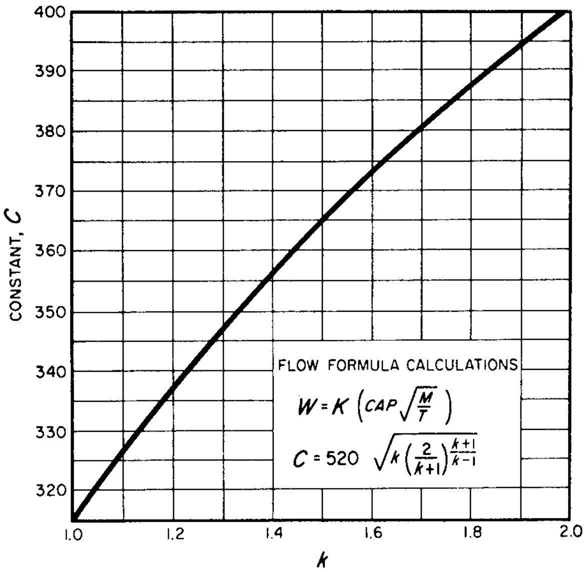
Official Rating in Steam

$$KA = \frac{W_s}{51.5P}$$

Official Rating in Air

$$KA = \frac{W_a}{CP}\sqrt{\frac{T}{M}}$$

This value for KA is then substituted in the above formulas to determine the capacity of the safety valve in terms of the new gas or vapor.



k	Constant C	k	Constant C	k	Constant C
1.00	315	1.26	343	1.52	366
1.02	318	1.28	345	1.54	368
1.04	320	1.30	347	1.56	369
1.06	322	1.32	349	1.58	371
1.08	324	1.34	351	1.60	372
1.10	327	1.36	352	1.62	374
1.12	329	1.38	354	1.64	376
1.14	331	1.40	356	1.66	377
1.16	333	1.42	358	1.68	379
1.18	335	1.44	359	1.70	380
1.20	337	1.46	361	2.00	400
1.22	339	1.48	363	2.20	412
1.24	341	1.50	364		

FIG. 2-100.1 CONSTANT C FOR GAS OR VAPOR RELATED TO RATIO OF SPECIFIC HEATS ($k = c_p/c_v$)

(*d*) When desired, as in the case of light hydrocarbons, the compressibility factor, Z, may be included in the formulas for gases and vapors as follows:

$$W = CKAP\sqrt{\frac{M}{ZT}}$$

Example No. 1:

Given: A safety valve bears a certified capacity rating of 3020 lb of steam per hour for a pressure setting of 200 psi.

Problem: What is the relieving capacity of that valve in terms of air at 100 F for the same pressure setting?

Solution:

For steam:

$$W_s = 51.5\ KAP$$

$$3020 = 51.5\ KAP$$

$$KAP = \frac{3020}{51.5} = 58.5$$

For air:

$$W_a = CKAP\sqrt{\frac{M}{T}}$$

$$= 356\ KAP\sqrt{\frac{28.97}{460 + 100}}$$

$$= (356)\ (58.5)\sqrt{\frac{28.97}{560}}$$

$$= 4750 \text{ lb per hour}$$

TABLE 2-100.1

MOLECULAR WEIGHTS OF GASES AND VAPORS

Air	28.97	Refrigerant 22	86.48
Acetylene	26.04	Refrigerant 114	170.90
Ammonia	17.03	Hydrogen	2.02
Butane	58.12	Hydrogen Sulfide	34.08
Carbon Dioxide	44.01	Methane	16.04
Chlorine	70.91	Methyl Chloride	50.48
Ethane	30.07	Nitrogen	28.02
Ethylene	28.05	Oxygen	32.00
Refrigerant 11	137.371	Propane	44.09
Refrigerant 12	120.9	Sulfur Dioxide	64.06

Example No. 2:

Given: It is required to relieve 5000 lb of propane per hour from a pressure vessel through a safety valve set to relieve at a pressure of P_s, pounds per square inch, and with an inlet temperature of 125 F.

Problem: What total capacity in pounds of steam per hour in safety valves must be furnished?

Solution:

For propane:

$$W = CKAP\sqrt{\frac{M}{T}}$$

Value of C is not definitely known. Use the conservative value, $C = 315$

$$5000 = 315\ KAP\sqrt{\frac{44.09}{460 + 125}}$$

$$KAP = 57.7$$

For steam:

$$W_s = 51.5\ KAP = (51.5)\ (57.7)$$
$$= 2790 \text{ lb per hour set to relieve at } P_s, \text{ pounds per square inch}$$

Example No. 3:

Given: It is required to relieve 1000 lb of ammonia per hour from a pressure vessel at 150 F.

Problem: What is the required total capacity in pounds of steam per hour at the same pressure setting?

Solution:

For ammonia:

$$W = CKAP \sqrt{\frac{M}{T}}$$

Manufacturer and user agree to use $k = 1.33$

From Fig. 2-100.1, $C = 350$

$$1000 = 350\ KAP \sqrt{\frac{17.03}{460 + 150}}$$

$$KAP = 17.10$$

For steam:

$$W_s = 51.5\ KAP = 51.5 \times 17.10$$
$$= 880 \text{ pounds per hour}$$

Example No. 4:

Given: A safety valve bearing a certified rating of 10,000 cu ft per minute of air at 60 F and 14.7 psia (atmospheric pressure).

Problem: What is the flow capacity of this safety valve in pounds of saturated steam per hour for the same pressure setting?

Solution:

For air:

Weight of dry air at 60 F and 14.7 psia is 0.0766 per cu ft.

$$W_a = 10{,}000 \times 0.0766 \times 60 = 45{,}960 \text{ lb per hour}$$

$$45{,}960 = 356\ KAP \sqrt{\frac{28.97}{460 + 60}}$$

$$KAP = 546$$

For steam:

$$W_s = 51.5\ KAP = (51.5)\ (546)$$
$$= 28200 \text{ lb per hour}$$

NON-MANDATORY APPENDIX 3 INSTALLATION AND OPERATION

3-100 INTRODUCTION

(*a*) The rules in this Appendix are for general information only, because they pertain to the installation and operation of pressure vessels, which are the prerogative and responsibility of the law enforcement authorities in those states and municipalities which have made provision for the enforcement of Section X of the Boiler and Pressure Vessel Code.

(*b*) It is permissive to use any deviations suggested herein from provisions in the mandatory parts of this Section of the Code when granted by the authority having legal jurisdiction over the installation of pressure vessels.

3-101 Access for Inspection

(*a*) Vessels subject to external degradation (see Par. D-140) shall be so installed that there is sufficient access to all parts of the exterior to permit proper inspection of the exterior, unless adequate protection against degradation is provided or unless the vessel is of such size and is so connected that it may readily be removed from its permanent location for inspection.

(*b*) Vessels having manholes, handholes, or cover plates to permit inspection of the interior shall be so installed that these openings are accessible.

(*c*) In vertical cylindrical vessels subject to chemical degradation from its contents, to insure complete drainage, the bottom head, if dished, should preferably be concave to pressure.

3-102 Marking on the Vessel

The marking required by the Code shall be so located that it will be accessible after installation and when installed shall not be covered with insulation or other material that is not readily removable (see Article S-1).

3-103 Pressure-Relieving Safety Devices

The general provisions for the installation of pressure-relieving devices are fully covered in Article R-5. The following paragraphs contain details in arrangement of stop valves for shut-off control of safety pressure-relief devices which are sometimes necessary to the continuous operation of processing equipment of such a complex nature that the shut-down of any part of it is not feasible. There are also rules in regard to the design of discharge piping from safety and relief valves, which can only be general in nature because the design engineer must fit the arrangement and proportions of such a system to the particular requirements in the operation of the equipment involved.

3-104 Stop Valves Between Pressure-Relieving Device and Vessel

(*a*) A vessel, in which pressure can be generated because of service conditions, may have a full-area stop valve between it and its pressure-relieving device for inspection and repair purposes only. When such a stop valve is provided, it shall be so arranged that it can be locked or sealed open, and it shall not be closed except by

an authorized person who shall remain stationed there during that period of the vessel's operation within which the valve remains closed, and who shall again lock or seal the stop valve in the open position before leaving the station.

(*b*) A vessel or system (see Par. R-512) for which the pressure originates from an outside source exclusively may have individual pressure-relieving devices on each vessel, or connected to any point on the connecting piping, or on any one of the vessels to be protected. Under such an arrangement, there may be a stop valve between any vessel and the pressure-relieving devices, and this stop valve need not be locked open, provided it also closes off that vessel from the source of pressure.

3-105 Stop Valves on the Discharge Side of a Pressure-Relieving Device (See Par. R-515)

A full-area stop valve may be placed on the discharge side of a pressure-relieving device when its discharge is connected to a common header with other discharge lines from other pressure-relieving devices on nearby vessels that are in operation, so that this stop valve when closed will prevent a discharge from any connected operating vessels from backing up beyond the valve so closed. Such a stop valve shall be so arranged that it can be locked or sealed in either the open or closed position, and it shall be locked or sealed in either position only by an authorized person. When it is to be closed while the vessel is in operation, an authorized person shall be present, and he shall remain stationed there; he shall again lock or seal the stop valve in the open position before leaving the station. Under no condition should this valve be closed while the vessel is in operation except when a stop valve on the inlet side of the safety relieving device is installed and is first closed.

3-106 Discharge Lines From Safety Devices

(*a*) Where it is feasible, the use of a short discharge pipe or vertical riser, connected through long-radius elbows from each individual device, blowing directly to the atmosphere, is recommended. Such discharge pipes shall be at least of the same size as the valve outlet. Where the nature of the discharge permits, telescopic (sometimes called "broken") discharge lines, whereby condensed vapor in the discharge line, or rain, is collected in a drip pan and piped to a drain, are recommended.[1]

(*b*) When discharge lines are long, or where outlets of two or more valves having set pressures within a comparable range are connected into a common line, the effect of the back pressure that may be developed therein when certain valves operate must be considered (see Par. R-530). The sizing of any section of a common-discharge header downstream from each of the two or more pressure-relieving devices that may reasonably be expected to discharge simultaneously shall be based on the total of their outlet areas, with due allowance for the pressure drop in all downstream sections. Use of specially designed valves suitable for use on high or variable back-pressure service should be considered.

(*c*) All discharge lines shall be run as direct as is practicable to the point of final release for disposal. For the longer lines, due consideration shall be given to the advantage of long-radius elbows, avoidance of close-up fittings, and the minimizing of excessive line strains by expansion joints and well-known means of support to minimize line-sway and vibration under operating conditions.

NOTE: It is recognized that no simple rule can be applied generally to fit the many installation requirements, which vary from simple short lines that discharge directly to the atmosphere to the extensive manifolded discharge piping systems where the quantity and rate of the product to be disposed of requires piping to a distant safe place.

3-107 General Advisory Information on the Characteristics of Safety-Relief Valves Discharging Into a Common Header

Because of the wide variety of types and kinds of safety-relief valves, it is not considered advisable to attempt a description in this Appendix of the effects produced by discharging them into a common header. Several different types of valves may conceivably be connected into the same discharge header and the effect of back pressure on each type may be radically different. Data compiled by the manufacturers of each type of valve used should be consulted for information relative to its performance under the conditions anticipated.

[1]This construction has the further advantage of not transmitting discharge-pipe strains to the valve. In these types of installation, the back-pressure effect will be negligible, and no undue influence upon normal valve operation can result.

APPENDIX 4
GLOSSARY OF TERMS RELATED TO FIBERGLASS-REINFORCED PLASTICS

ABL Bottle. A test, internal pressure vessel about 18 inches in diameter and 24 inches long, used to determine the quality and properties of the filament-wound material in the vessel.

Accelerator. A material which, when mixed with a catalyzed resin, will speed up the chemical reaction between the catalyst and resin.

A-Stage. An early stage in the reaction of certain thermosetting resins, in which the material is still soluble in certain liquids and fusible. Sometimes referred to as Resol. (See also *B-Stage* and *C-Stage.*)

Axial Winding. In filament-wound, fiberglass-reinforced plastics, a winding with the filaments parralled to the longitudinal axis (zero degree helix angle).

B-Stage. An intermediate stage in the reaction of certain thermosetting resins in which the material swells when in contact with certain liquids and softens when heated, but may not entirely dissolve or fuse. The resin in an uncured prepreg or premix is usually in this stage. Sometimes referred to as Resitol. (See also *A-Stage* and *C-Stage.*)

Balanced Design. In filament-wound reinforced plastics, a winding pattern designed so as to have equal stresses in all filaments.

Balanced-In-Plane Contour. In a filament-wound part, a head contour in which the filaments are oriented within a plane and the radii of curvature are adjusted to balance the stresses along the filaments with the pressure loading.

Band Density. In filament-winding, the quantity of fiberglass reinforcement per inch of band width, expressed as strands (or filaments) per inch.

Band Thickness. In filament-winding, the thickness of the reinforcement as it is applied to the mandrel.

Band Width. In filament-winding, the width of the reinforcement as it is applied to the mandrel.

Biaxial Load. A loading condition whereby a laminate is stressed in at least two different directions in the plane of the laminate. The loading condition of a pressure vessel under internal pressure and with unrestrained ends.

Biaxial Winding. A type of winding in which the helical band is laid in sequence, side by side, eliminating crossover of the fibers.

Bidirectional Laminate. A reinforced plastic laminate with the fibers oriented in various directions in the plane of the laminate. (See also *Unidrectional Laminate.*)

Bleedout. In filament-wound, fiberglass-reinforced plastics, the excess liquid resin that migrates to the surface of a winding.

Bushing. The unit through which molten glass is drawn in making glass fibers.

C-Stage. The final stage in the reaction of certain thermosetting resins in which the material is relatively insoluble and infusible. The resin in a fully cured thermoset molding is in this stage. Sometimes referred to as Resite. (See also *A-Stage* and *B-Stage.*)

Catalyst. A material which, when mixed with a resin, will react chemically with the resin to produce a cured thermoset.

Catenary. The tendency of some strands in a taut horizontal roving to sag lower than the others.

A measure of the evenness of length (of winding tension indirectly) of strands in a specified length of roving. The distance between the strands at the midpoint of a roving draped in a catenary in a specified manner. (Also see *Strand Length Differential.*)

Circs. Hoop windings.

Circuit. One complete traverse of the fiber feed mechanism of a winding machine.

In filament-wound, fiberglass-reinforced plastics, one complete traverse of a winding band from one arbitrary point along the winding path to another point on a plane through the starting point and perpendicular to the axis.

Circumferential (Circ.) Winding. In filament-wound, fiberglass-reinforced plastics, a winding with the filaments essentially perpendicular to the axis (90 degree or level winding).

Compact Winding. See *Biaxial Winding.*

Compatibility. Usually refers to the suitability of a sizing or finish for use with certain general resin types. For instance, polyester compatible roving, epoxy compatible roving, etc.

Contact Molding. A process for molding reinforced plastics in which reinforcement and resin are placed on a low cost mold, cure is either at room temperature using a catalyst-promoter system or by heat in an oven and no additional pressure is used.

Coupling Agent. In glass fibers for reinforced plastics, that part of a sizing or finish which is designed to provide a bonding link between the glass surface and the laminating resin.

Crazing. In a reinforced plastic, the appearance of fine cracks in the resin, usually as a result of excessive resin shrinkage, or some external loading condition.

Creel. An apparatus for holding a number of packages of strand, yarn, roving, tape, etc. Tensioning devices are sometimes included on the creel.

Cure. To change the properties of a plastic by chemical reaction, which may be condensation, polymerization, or addition; usually accomplished by the action of heat or catalyst or both, with or without pressure.

Delamination. The physical separation or loss of bond between laminate plies.

Displacement Angle. In filament-winding, the advancement distance of the winding ribbon on the equator after one complete circuit.

Doily. A reinforcement for openings. See *Wafer.*

In filament-winding, the planar reinforcement that is applied to a local area between windings to provide extra reinforcement in an area where a cut-out is to be made.

Doubler. In a filament-wound part, a local area with extra-wound reinforcement, wound integrally with the part, or wound separately and fastened to the part.

Dry Laminate. A laminate containing insufficient resin for complete bonding of the reinforcement.

Dry Spot. In a laminate, an area containing insufficient resin for complete bonding of the reinforcement.

Dry Winding. Filament-winding reinforced plastics with prepreg. (See also *Wet Winding.*)

A process in which preimpregnated B-staged fibers are used in the winding.

Dwell. In filament-winding, the time that the traverse mechanism is stationary while the mandrel continues to rotate to the appropriate point for the traverse to begin a new pass.

E-Glass. A borosilicate glass; the type most used for glass fibers for reinforced plastics. Suitable for electrical laminates because of its high resistivity.

End. In continuous filament glass roving, the loosely bonded bundle of continuous filaments formed and sized together. (See also *Strand.*)

Epoxy. Synthetic resin containing a reactive group in which an oxygen atom is joined to each of two carbon atoms which are already united in some other way $\underset{\diagdown O \diagup}{-C-C-}$.

Equator. In a filament-wound pressure vessel, the line described by the juncture of the cylindrical portion and the end dome.

Fabric. A planar structure produced by interlacing yarns, rovings, etc.

Fiber. An individual filament made by attenuating molten glass. A continuous filament is a glass fiber of indefinite length.

Filament-Winding. A process for fabricating a composite structure in which continuous reinforcements (filament, wire, yarn, tape or other), either previously impregnated with a matrix material or impregnated during winding, are placed over a rotating and removable form or mandrel in a previously prescribed way to meet certain stress conditions. Generally the shape is a surface of revolution and may or may not include end closures.

Filler. A relatively inert nonfibrous material added to a plastic to modify its strength, permanence, working properties, or other qualities, or to lower costs.

Finish. A material applied to the surface of glass fibers used to reinforce plastics and intended to improve the physical properties of such reinforced plastics over that obtained using glass reinforcement without finish. (See *Sizing*).

Forming. A phase of the fiberglass production operation in which the glass fiber strands are drawn from the bushing.

Fuzz. Accumulation of short broken filaments after passing glass strands, yarns or rovings over a contact point. Often weighted and used as an inverse measure of abrasion resistance.

Gap. In filament-winding, the space between successive windings, which windings are usually intended to lay next to each other.

Gel. The initial jelly-like solid phase that develops during the cure of a thermosetting resin.

Gel Coat. A resin applied to the surface of a mold and gelled prior to lay-up. The gel coat becomes an integral part of the finished laminate and is usually used to improve surface appearance, etc.

Gel Time. Time lapsed as read on the actual exotherm curve between 150F and 10 degrees above the (180F) bath temperature (hence 190F). This definition applies for any desired reference (bath) temperature.

Geodesic. The shortest distance between two points on a surface.

Geodesic Isotensoid. See *Geodesic Ovaloid.* Isotensoid refers to constant stress level in any given filament at all points in its path.

Geodesic Isotensoid Contour. In filament-wound, fiberglass-reinforced plastic pressure vessels, a dome contour in which the filaments are placed on geodesic paths so that the filaments will exhibit uniform tensions throughout their length under pressure loading.

Geodesic Ovoloid. A countour for end domes, the fibers forming a "geodisic line"– the shortest distance between two points on a surface of revolution. The forces exerted by the filaments are proportioned to match the hoop and meridional stresses at any point.

Geodesic Ovaloid Contour. See *Geodesic Isotensoid.*

Glass. An inorganic product of fusion which has cooled to a rigid condition without crystallizing.

Glass Fiber. A glass filament that has been cut to a measurable length. Staple fibers of relatively short length and suitable for spinning into yarn.

Glass Filament. A form of glass that has been drawn to a small diameter and extreme length. Most glass filaments are less than 0.0005 inch in diameter.

Glass Stress. In a filament-wound part, usually a pressure vessel, the stress calculated using the load and the cross-sectional area of the reinforcement only.

Hand Lay-Up. The process of placing and working successive plies of the reinforcing material or resin-impregnated reinforcement in position on a mold by hand.

Head. The end closure(s) of a cylindrical container which may be integral in the case of filament-wound vessels or separately fabricated in the case of bag-molded or centrifugally cast vessels.

Helical Winding. In filament-wound, fiberglass-reinforced plastics, a winding in which a filament band advances along a helical path, not necessarily at a constant angle, except in the case of a cylinder.

High Pressure Molding. A molding process in which the pressure used is greater than 200 psi.

Impregnate. In fiberglass-reinforced plastics, saturation of the reinforcement with a resin.

Inhibitor. A material added to a catalyzed resin to slow down cure at approximately room temperature. Usually used in prepreg or premix resins.

Interface. On glass fibers, the contact area between glass and sizing (or finish). In a laminate, the contact area between the glass, sizing or finish and the laminating resin.

Interlaminar Shear Strength. The maximum shear stress existing between layers of a laminated material.

Isotensoid. Constant tension.

Isotropic Laminate. A laminate in which the strength properties are equal in all directions.

Knuckle. The point at the end of a way-wound roving ball where the roving reverses its axial direction.

Knuckle Area. The region in a rocket motor chamber end dome region near the juncture with the cylindrical portion.

In a filament-wound part, the area of transition between two different general shapes, e.g., the transition from a central cylindrical portion and the end dome.

Laminate. A product made by bonding together two or more layers of material or materials.

Laminate Ply. One layer of a product made by bonding together two or more layers or material.

Lap. In filament-winding, the amount of overlay between successive windings, usually intended to minimize gapping.

Lattice Pattern. In filament-winding, a pattern with a fixed arrangement of open voids giving a basketweave effect.

Lay. In filament-winding, the orientation of the ribbon with some reference, usually the axis of rotation.

Lay-Up. (1) A laminate that has been assembled, but not cured. (2) A description of the component materials, geometry, etc. of a laminate.

Level Winding. See *Circumferential Winding.*

Liner. In a filament-wound pressure vessel, the continuous, usually flexible coating on the inside surface of the vessel, used to protect the laminate from chemical attack or to prevent leakage under stress.

Longos. Low angle helical or longitudinal windings.

Loops and Snarls. A place in a roving where one or more short lengths of strand have doubled back on themselves.

Loss-on-Ignition. Weight loss, usually expressed in percent of total, after burning off an organic sizing from glass fibers or an organic resin from a glass fiber laminate.

Low-Pressure Molding. Molding or laminating in which the pressure used is between 15 and 200 psi.

Lubricant. A material added to most sizings to improve the handling and processing properties of strand.

Mandrel. In filament-winding, the mold on which the laminating material is wound.

Mat. A glass fiber material for fiberglass-reinforced plastic laminates consisting of randomly oriented chopped strands or swirled strands with a binder and available in blankets of various widths and lengths.

Mat-Binder. A resin which is applied to glass strands and cured during the manufacture of mat to hold the strands in place and maintain the shape of the mat.

Matrix. See *Resin.*

Multi-Circuit Winding. In filament-wound, fiberglass-reinforced plastics, a winding that requires more than one circuit before the band repeats by laying adjacent the first hand.

Netting Analysis. The analysis of filament-wound structures which assumed that the stresses induced in the structure are carried entirely by the filaments, and the strength of the resin is neglected; and also that the filaments possess no bending or shearing stiffness, and carry only axial loads.

Nol Ring. A parallel filament-wound test specimen used for measuring various mechanical strength properties of the material by testing the entire ring, or segments of it. The ring is usually 146.05 mm (5.750 in.) in inside diameter by 6.35 mm (0.250 in.) wide by either 1.52 mm (0.060 in.) or 3.18 mm (0.125 in.) in wall thickness.

Ovaloid. A surface of revolution symmetrical about the polar axis which forms the end closure for a filament-wound cylinder.

Phenolic. Synthetic condensation resins of aldehyde and phenols. The common reactants are formaldehyde and phenol and cresol.

Planar Winding. A winding in which the filament path lies on a plane which intersects the winding surface.

Planar Helix Winding. A winding in which the filament path on each dome lies on a plane which intersects the dome, while a helical path over the cylindrical section is connected to the dome paths.

Plasticizer. A material added to a resin to facilitate compounding and improve flexibility and other properties of the finished product.

Plied Yarn. A yarn formed by twisting together two or more single yarns in one operation.

Polar Winding. A winding in which the filament path passes tangent to the polar opening at one end of the chamber, and tangent to the opposite side of the polar opening at the other end. A one circuit pattern is inherent in the system.

Pole Piece. In filament-winding, a winding in which the filament path lies on a plane which intersects the winding surface.

In a pressure vessel, the metal reinforcements placed at both ends of the major axis of the vessel. Their extension into the end dome depends on stress conditions.

Polyester. A class of thermosetting synthetic resins produced by the esterification of polybasic organic acids or anhydrides with polyhydric alcohols.

Post Cure. Additional oven cure, usually without pressure, after initial cure to improve final properties of reinforced plastic laminates.

Pot Life. The length of time that a resin system retains a viscosity low enough to be used in laminating.

Preform. A coherent, shaped mass of fibrous reinforcement material with or without a binder resin.

Preform Binder. A resin applied to the chopped strands of a preform, usually during its formation, and cured so that the preform will retain its shape and can be handled.

Premix. In reinforced plastics, the admixture of resin, catalyst, reinforcements, fillers, etc., not in web or filamentous form, to provide a complete mix ready for molding.

Prepreg. In reinforced plastics, the admixture of resin, catalyst, reinforcements, fillers, etc., in web or filamentous form, to provide a complete mix ready for molding.

Pressure Bag-Molding. A process for molding reinforced plastics in which a tailored flexible bag is placed over the contact lay-up on the mold, sealed and clamped in place. Fluid pressure (usually compressed air) is placed against the bag and the part is cured.

Promotor. See *Accelerator.*

Random Pattern. A winding with no fixed pattern. If a large number of circuits are required for the pattern to repeat, a random pattern is approached.

Reinforced Plastic. A plastic with some strength properties greatly superior to those of the base resin, resulting from the presence of high-strength fillers imbedded in the composition.

NOTE: The reinforcing fillers are usually fibers, fabrics or mats made of fibers.

Reinforcement. A material which can be added to a resin matrix in order to strengthen and improve the properties of the resin.

Release Agent. A material which is applied in a thin film to the surface of a mold to keep the laminating resin from bonding to the mold.

Resin. In reinforced plastics, the material used to bind together the reinforcement material. Also referred to as *Matrix.*

Resin Applicator. In filament-winding, the device which deposits the liquid resin onto the reinforcement band.

Resin Content. The amount of resin in a laminate expressed as either a percent of total weight or total volume.

Resin Flexibilizer. See *Plasticizer.*

Reverse Helical Winding. A multi-circuit winding. As the fiber delivery area traverses one circuit, a continuous helix is laid down, reversing direction at the polar ends. It is contrasted to biaxial, compact of sequential winding in that the fibers cross each other at definite equators, the number depending on the helix angle. The minimum region of crossover would be three.

Ribbonization. The degree of flattening of a sized roving; expressed as the ratio of ribbon width to thickness.

Ribbon Width. See *Band Width.*

Ring Punchout Shear Strength. The interlaminar shear strength of a filament-wound cylinder at a predetermined shear plane.

Roving. An assemblage of a number of strands or ends, roughly parallel and with very little twist.

Roving Ball. Package, usually cylindrically wound, of continuous roving.

Roving Ball Build. The geometry of a roving ball, including a description of the way-wind.

Roving Integrity. The degree of bond between strands in a roving.

S-Glass. A magnesia-alumina-silicate glass, expecially designed to provide very high tensile strength glass filaments.

Sequential Winding. See *Biaxial Winding.*

Shelf Life. Useful storage life of materials used in fiberglass-reinforced plastics.

Shelling. A term applied to loops of roving falling to the base of a roving ball as the roving is payed out from a roving ball on end.

Short Beam Shear Strength. The interlaminar shear strength of a parallel fiber reinforced plastic material as determined by three-point flexural loading of a short segment cut from a ring-type specimen.

Silicone. Semi-organic polymers made up of a skeleton structure of alternate silicon and oxygen atoms with various organic groups attached to the silicon.

Single-Circuit Winding. A winding in which the filament path makes a complete traverse of the chamber, after which the following traverse lies immediately adjacent to the previous one.

Size. To apply compounds to a strand, which compounds form a more or less continuous film around the strand and individual fibers.

Sizing. On glass fibers, the compounds which, when applied to filaments at forming, provide a loose bond between the filaments, and provide various desired handling and processing properties. For reinforcing plastics, the sizing will also contain a coupling agent.

Sizing Content. The percent of the total strand weight made up by the sizing. Usually determined by burning off the organic sizing. (Also see *Loss-on-Ignition*).

Sizing Extractables. The percent of the total sizing weight that can be extracted with acetone, or some other applicable solvent. Measured primarily on certain reactive sizings to determine degree of cure.

Skein. A continuous strand, yarn, roving, etc., wound up to some measurable length, and usually used to measure various physical properties of the material.

Skirt. In a filament-wound bottle, that material added to the end (or ends) to provide an attachment point for supporting the bottle.

An extension of the cylindrical portion of a motor case from the equator, used for interstage connections, usually wound as an intergral part of the case.

Splice. The joining of two ends of glass fiber yarn or strand, usually by means of an air-drying glue.

Spray-Up. A process for laying up reinforced plastics in which a special "gun" chops glass roving and sprays resin and a curing agent or catalyst-accelerator on the mold. The layup is then usually worked by hand.

Stiffness. A measure of the flexural rigidity of glass fiber strands, yarns, rovings, etc. The resistance of roving or yarn to flexure.

Strand. An assembly of continuous filaments, without twist. A loosely bonded assemblage of glass fibers or glass filaments; the immediate product of the multi-fiber forming process. Also known as an 'end'.

Strand Count. The number of strands in a plied yarn; the number of strands in a roving.

Strand Integrity. The degree of bond between the filaments in a strand.

Strand Length Differential. Similar to catenary, a measure of the difference in length of the strands or yarns in a roving, the difference being caused by uneven tension, way-wind, etc. (Also see *Catenary.*)

Strand Tensile Strength. The tensile strength of a glass-fiber strand, yarn or roving, when tested as a straight specimen.

Surface Mat. A very thin mat, usually 7 to 20 mils thick, or highly filamentized fiberglass used primarily to produce a smooth surface on a fiber-glass-reinforced plastic laminate.

Tack. With special reference to prepreg materials, the degree of stickness of the resin.

Tangent Line. In a filament-wound bottle, any diameter at the equator.

Tangent Point. In a filament-wound bottle, any point on the equator.

Thermoplastic. A plastic which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

Thermoset. A plastic which, when cured by application of heat or chemical means, changes into a substantially infusible and insoluble material.

Thixotropic. The capacity of a liquid material to have high static shear strength (viscosity) and at the same time low dynamic shear strength. Such a material can be mixed (stirred), but will not flow under the force of gravity.

Treater. Equipment arrangement providing for (1) delivery of continuous web or strand to resin impregnating tank, (2) means of controlling resin pickup, (3) drying area for desolvating and/or partially curing the resin, and (4) rewind for resin-impregnated reinforcement. Product to be subsequently used in forming with heat and pressure.

Turns Per Inch (TPI). A measure of the amount of twist produced in a yarn during its conversion from strand.

Twist. The turns about its axis per unit of length observed in a yarn or other textile strand. Twist may be expressed as turns per inch (TPI), etc. "S" and "Z" refer to direction of twist.

Twisting. An operation by which a strand or sliver is given a pre-established number of turns per inch and is thus converted into a yarn, thread or cord.

Uniaxial Load. A loading condition whereby a laminate is stressed in only one direction.

Unidirectional Laminate. A reinforced plastic laminate in which all the fibers are oriented in the same direction.

Vacuum Bag-Molding. A process for molding fiberglass-reinforced plastics in which a sheet of flexible transparent material is placed over the layup on the mold and sealed. A vacuum is applied between the sheet and the layup. The air is mechanically worked out of the layup and removed by the vacuum. The part is cured.

Veil. An ultrathin mat similar to a surface mat, often comprising organic fibers as well as glass fibers.

Voids. Air pockets that have been trapped and cured into a laminate.

Volatiles. Materials in a roving sizing or a resin formulation which are capable of being driven off as a vapor at room or slightly elevated temperature.

Wafer. A reinforcement for openings.

Wall Stress. In a filament wound part, usually a pressure vessel, the stress calculated using the load and the entire laminate cross-sectional area. (Also see *Glass Stress.*)

Waywind. The number of wraps or turns that an end or ends make from one side of the wound package back to the same side.

Wet Lay-up. A reinforced plastic which has liquid resin applied as the reinforcement is being laid up.

Wet-Out. The condition of an impregnated roving or yarn wherein substantially all voids between sized strands and filaments are filled with resin.

Wet Winding. Filament-winding reinforced plastics when the fiber reinforcement is coated with liquid resin just prior to wrapping on the mandrel.

Wetout Rate. The time required for a plastic to fill the interstices of a reinforcement material and wet the surface of the reinforcement fibers. Usually determined by optical or light transmission means.

Winding Pattern. A total number of individual circuits required for a winding path to begin repeating by laying down immediately adjacent to the initial circuit.

A regularly recurring pattern of the filament path after a certain number of mandrel revolutions, leading to the eventual complete coverage of the mandrel.

Winding Tension. In filament-winding, the amount of tension on the reinforcement as it makes contact with the mandrel.

Yardage. Number of yards of yarn, roving strand, etc., per pound of glass fibers. The reciprocal of weight per yard.

Yarn. One strand which has been twisted, or two or more twisted strands which have been plied.

A generic term for a continuous strand of textile fibers, filament or material in a form suitable for knitting, weaving or otherwise inter-twining to form a textile fabric.

Yarn Construction. A term used to indicate the number of a single yarn and the number of strands combined to form each successive unit of a plied yarn or cord.

FORM Q-106

RECOMMENDED FORM FOR QUALIFYING THE VESSEL DESIGN AND THE PROCEDURE SPECIFICATION USED IN FABRICATING BAG-MOLDED AND CENTRIFUGALLY CAST[1] FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

PROCEDURE SPECIFICATION NO. ______________ PROCESS ______________

A change in any of the essential variables denoted by an asterisk in succeeding paragraphs requires a new Procedure Specification.

*FIBERGLASS ______________
(Insert Type of Fiberglass or Reference to Applicable Specification)

*SIZING ______________
(Manufacturer and Designation)

____

____

FORM OF REINFORCEMENT ______________
(Insert Cut Strand, Mats or Preforms)

BINDER FOR MATS AND PREFORMS ______________
(Insert Type of Binder, Polyester Emulsion, Polyester in Alcohol, Polyester Powder, etc.)

WEIGHT OF BINDER ______________ SOLUBILITY ______________
(Percent) (High or Low Resistance to Styrene, ASTM D-1529, Seconds)

MATS ______________
(Oz. per Sq. Ft., 1½, 2 or 3)

PREFORMS ______________
(Weight of Binder Percent)

*RESIN ______________
(Epoxy, Polyester, Trade Name or Specification)

*CURING AGENT ______________
(Chemical Name, Trade Name or Specification)

VISCOSITY OF RESIN SYSTEM ______________

*CURE

Mandrel ______________
(Time) (Temperature)

Mold ______________
(Time) (Temperature)

*POST CURE

Furnace ______________
(Time)

*PERCENT GLASS IN COMPOSITE ______________

SPECIFIC GRAVITY OF COMPOSITE (ASTM D-792) ______________

INITIAL BAG PRESSURE ______________

FINAL BAG PRESSURE ______________

RESIN INJECTION PRESSURE ______________

*WEIGHT OF VESSEL ______________

*BARCOL HARDNESSES AND LOCATION ______________

____

[1] For Filament-Winding Procedure Specification, see Form Q-107.

*VOLUMETRIC EXPANSION ______________________________ cu. in.
*MANDREL ROTATION, RPM (CENTRIFUGAL-CASTING) ______________________________

LINER ______________________________
(Material) (Thickness)

QUALIFICATION
Vessel (s) Serial Number(s) ______________________________
Design Report Number ______________________________
Test Report Number ______________________________

We certify that the statements made in this Specification are correct:

Date ______________ 19____ Signed ______________________________
(Manufacturer)

By ______________________________

Certificate of Authorization Expires ______________________________

CERTIFICATION BY SHOP INSPECTOR OF QUALIFICATION OF DESIGN AND FABRICATION PROCEDURE

PROCEDURE SPECIFICATION OF ______________ at ______________________________
for ______________________________ process of manufacturing vessel (s) described in
______________________________ Design Specification and ______________________________
(User) (Manufacturer)

______________________________ Design Report Number ______________________________

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______________________________ and employed by ______________ of ______________ have witnessed the tests by which the design of the vessel (s) and the fabrication procedure have been qualified and state that, to the best of my knowledge and belief, these tests of the prototype vessel (s) and the fabrication procedure employed in constructing the vessel (s) satisfy the requirements of Section X of the ASME Boiler and Pressure Vessel Code for Fiberglass-Reinforced Plastic Pressure Vessels.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the design or procedure covered by the Manufacturer's Design Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or loss of any kind arising from or connected with this inspection.

Date ______________ 19____ Commissions ______________________________
National Board, State or Province and No.

____
Inspector's Signature

FORM Q-107

RECOMMENDED FORM FOR QUALIFYING THE VESSEL DESIGN AND THE PROCEDURE SPECIFICATION USED IN FABRICATING FILAMENT-WOUND FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

PROCEDURE SPECIFICATION NO. ____________________

A change in any of the essential variables denoted by an asterisk in succeeding paragraphs requires a new Procedure Specification.

*FIBERGLASS ____________________
(Ends per Roving, Class Composition, Filament Dia., Yield per End, Yarn Construction)

*SIZING OR FINISH ____________________
(Manufacturer and Designation)

*RESIN ____________________
(Manufacturer and Designation)

*CURING AGENT ____________________
(Manufacturer and Designation)

VISCOSITY OF RESIN SYSTEM __________ cp. (min.) to __________ cp. (max.) @ __________ F.

*MANNER OF IMPREGNATION ____________________
(Prepreg, wet wind, postpreg)

*PERCENT GLASS IN COMPOSITE ____________________

*VARIABLES OF WINDING PROCESS

Helix Angle: __________ (measured on cylinder between axis and band path)

Pattern Description: ____________________

Band Density: Helical __________ end/in. Circumferential __________ end/in.

Band Width: Helical __________ in. Circumferential __________ in.

Band Velocitu: Helical __________ ft./min. Circumferential __________ ft./min.

Tension: Per Strand (End), Roving, or Band (specify which) __________ lbs. per __________

Method of Control: __________ Program __________

Layer Sequence: __________ (Note 1) Ratio Hel./Circ. in Cylinder __________

*CURING SCHEDULE: __________ F for __________ hrs. __________ min.
__________ F for __________ hrs. __________ min.
__________ F for __________ hrs. __________ min.
__________ F for __________ hrs. __________ min.
__________ F for __________ hrs. __________ min.

Manner of Measuring Temperature: Oven Air __________ Winding Surface __________

Mandrel __________ Other __________ (Describe)

*LINER ____________________
(Material Specification or Manufacturer Designation) (Thickness)

____
(Method of Installing Liner)

Note 1 Use X to indicate layer of helical windings
O to indicate full layer of circumferential windings (down and back)
o to indicate half-layer of circumferential windings (one pass)
Where a range of values or a tolerance applies, state the applicable range or tolerance.

FORM Q-107 (Cont.)

MANNER OF REINFORCING OPENINGS ____________________
(Describe)

*POLE PIECES ____________________
(Material)

____
(Method of installing: wound-in, bonded, etc.)

____
(Auxiliary Uses)

HEAD CONTOUR ____________________
(Describe)

TYPE OF MANDREL ____________________
(Describe)

TYPE OF WINDING MACHINE ____________________
(Describe)

*WEIGHT OF VESSEL ____________________

*BARCOL HARDNESSES AND LOCATION ____________________

*VOLUMETRIC EXPANSION ____________________

QUALIFICATION: Vessel (s) Serial Number (s) __________ Design Report Number __________

__________ Test Report Number __________

We certify that the statements in this Specification are correct.

Date __________ 19______ Signed ____________________
(Manufacturer)

By ____________________

Certificate of Authorization Expires ____________________

CERTIFICATION BY SHOP INSPECTOR OF QUALIFICATION OF DESIGN AND FABRICATION PROCEDURE

PROCEDURE SPECIFICATION OF __________ at __________

for __________ process of manufacturing vessel (s) described in

__________ Design Specification and __________
(User) (Manufacturer)

__________ Design Report Number __________

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of __________

and employed by __________ of __________

have witnessed the tests by which the design of the vessel (s) and the fabrication procedure have been qualified and state that, to the best of my knowledge and belief, these tests of the prototype vessel (s) and the fabrication procedure employed in constructing the vessel (s) satisfy the requirements of Section X of the ASME Boiler and Pressure Vessel Code for Fiberglass-Reinforced Plastic Pressure Vessels.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the design or procedure covered by the Manufacturer's Design Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or loss of any kind arising from or connected with this inspection.

Date __________ 19______ Commissions ____________________
National Board, State or Province and No.

____
Inspector's Signature

FORM Q-115

RECOMMENDED FORM FOR QUALIFYING THE DESIGN AND THE PROCEDURE SPECIFICATION USED IN ADHESIVE-BONDING OF PARTS OF FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

PROCEDURE SPECIFICATION NO. ____________________

A change in any of the essential variables, denoted by an asterisk in succeeding paragraphs, requires a new Procedure Specification.

*ADHESIVE ____________________
(Insert Epoxy, Polyester, Trade Name)

*CURING AGENT ____________________
(Chemical Description, Trade Name)

*PREPARATION OF SURFACES ____________________
(Machining, Grinding, Degreasing)

*APPLICATION OF ADHESIVE ____________________
(Dip) (Brush)

*CURE ____________________
(Time) (Temperature)

LAMINATE USED IN TEST:

A. From Cylindrical Shell: Outside Diameter __________ Wall Thickness __________
Length of Lap*, L_____ Glass Content __________ Other Information __________

B. From Fabricated Flat Laminate: Thickness __________ Glass Content __________
Length of Lap*, L_____ Other Information __________

*As required for tensile test per Figs. Q-115.1 and Q-115.2.

REDUCED SECTION TENSION SPECIMEN OF BONDED JOINT DIMENSIONED SAME AS TYPE 1 SPECIMEN OF ASTM D638

Thickness of Wall	Reduced Width	Width Grip	Overall Length
¼ in. or Under	½	¾	8.5
Over ¼ – ½ in. incl.	¾	1⅛	9.7
Over ½ – 1 in. incl.	1	1½	12

CONDITION OF SPECIMEN

Specimen shall be wiped dry; no other conditioning is required.

RECORD OF SPECIMENS TESTED

	Dimensions					
Specimen No.	Thickness	Reduced Width	Length Of Bond Overlap	Area of Bond	Total Load Lb	Shear Stress
1						
2						
3						

QUALIFICATION OF VESSEL WITH BONDED JOINTS:

Vessel (s) Serial Number (s) ______________________

Design Report Number ______________________

Test Report Number ______________________

We certify that the statements in this Specification are correct.

Date ______________ 19______ Signed ______________________
(Manufacturer)

By ______________________

Certificate of Authorization Expires ______________________

CERTIFICATION BY SHOP INSPECTOR OF QUALIFICATION OF ADHESIVE-BONDING PROCEDURE

PROCEDURE SPECIFICATION OF ______________ at ______________

for ______________________ process of manufacturing vessel (s) described in

______________________ Design Specification and ______________
(User) (Manufacturer)

______________________ Design Report Number ______________

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______________________ and employed by ______________________ of ______________ have witnessed the tests by which the design of the joint(s) and the adhesive-bonding procedure have been qualified and state that, to the best of my knowledge and belief, these tests of the prototype joint(s) and the adhesive-bonding procedure employed in constructing the vessel (s) satisfy the requirements of Section X of the ASME Boiler and Pressure Vessel Code for Fiberglass-Reinforced Plastic Pressure Vessels.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the design or procedure covered by the Manufacturer's Design Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or loss of any kind arising from or connected with this inspection.

Date ______________ 19______ Commissions ______________________
National Board, State or Province and No.

____
Inspector's Signature

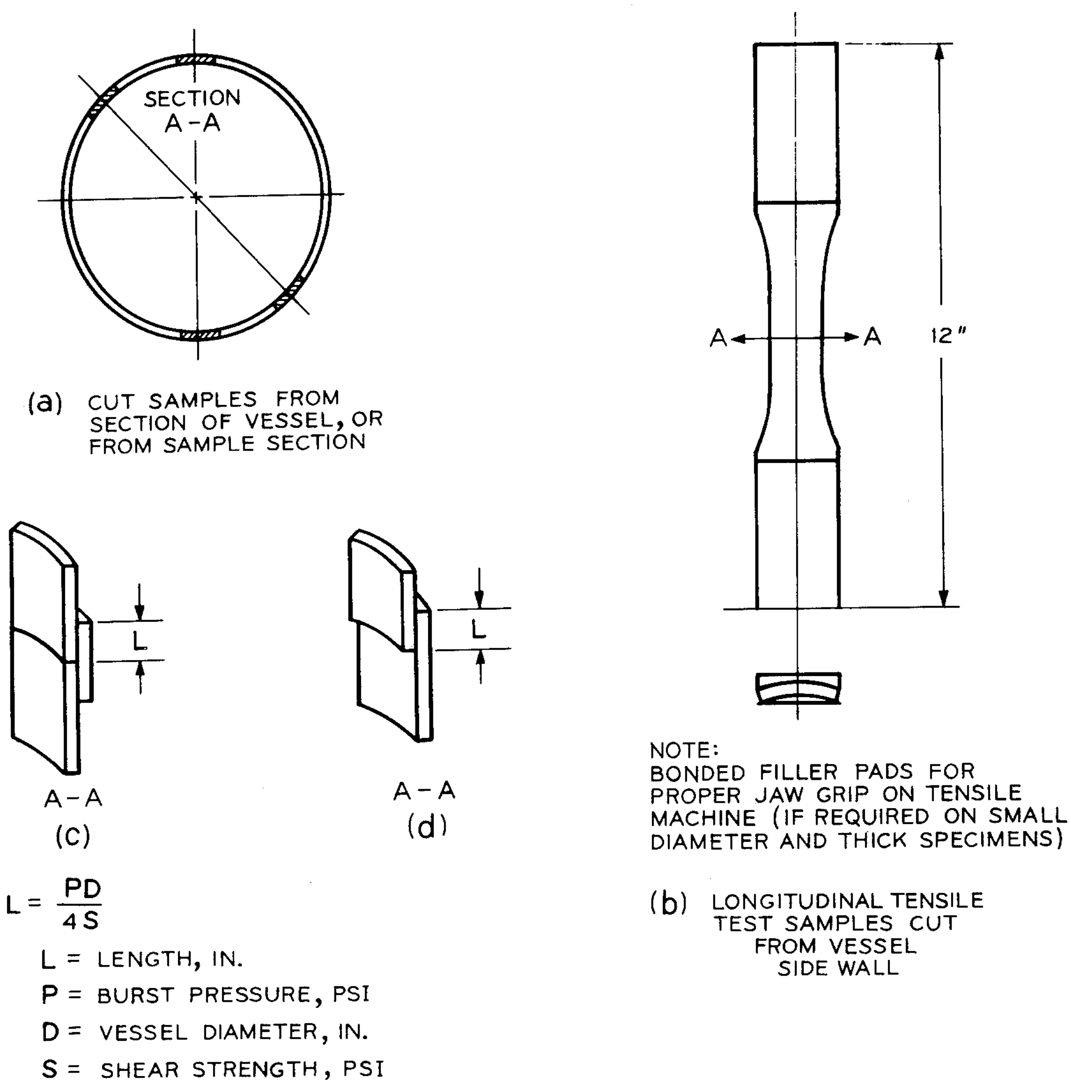
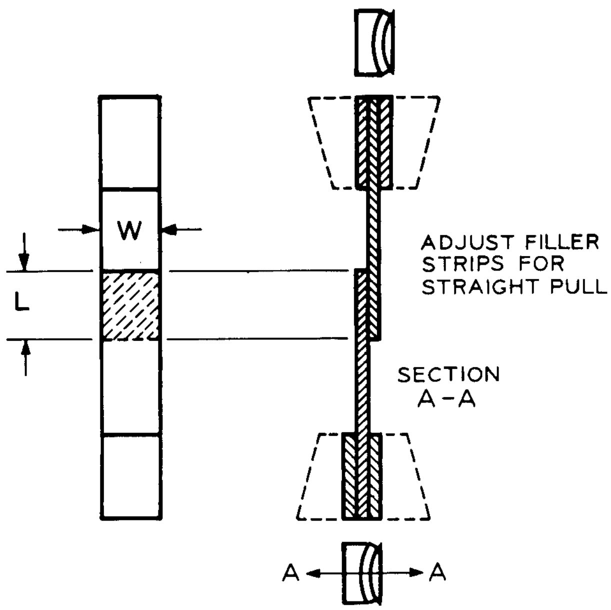
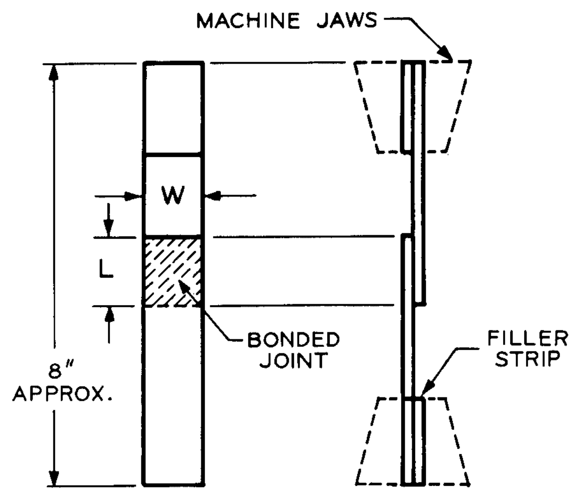


FIG. Q-115.1 SCHEMATIC VIEWS OF PERMISSIBLE JOINT DESIGNS FOR ADHESIVE-BONDED CYLINDER JOINTS FOR TENSILE TESTS



NOTE: USE FILLERS FOR CURVED SECTIONS

(e) SPECIMEN FABRICATED FROM CYLINDER OF VESSEL



NOTE: FILLERS NOT REQUIRED FOR THIN LAMINATES THAT CAN BE PULLED INTO FLAT PROFILE BY MACHINE JAWS

(f) SPECIMEN FABRICATED FROM FLAT LAMINATE

RECORD OF SPECIMENS TESTED

SPECIMEN	WIDTH "W" (1" RECOMMENDED)	LENGTH "L" (2" RECOMMENDED)	AREA OF BOND SQ. IN.	LBS. LOAD TO FAILURE	SHEAR STRENGTH OF JOINT, P.S.I.
1					
2					
3					
4					
5					
6					

TEST MACHINE NUMBER AND MAKE ____________________ PULL RATE __________

FIG. Q-115.1 (Continued) SCHEMATIC VIEWS OF PERMISSIBLE JOINT DESIGNS FOR ADHESIVE-BONDED CYLINDER JOINTS FOR TENSILE TESTS

FORM RP-1
MANUFACTURERS' DATA REPORT
FOR FIBERGLASS-REINFORCED PLASTIC PRESSURE VESSELS

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code

1. Manufactured by ____________________ (Name and address of Manufacturer)

2. Manufactured for ____________________ (Name and address of Purchaser)

3. Type ________ (Horiz. or Vert.) Vessel No. ________ (Mfrs. Serial) (State & State No.) Natl. Bd. No. ________

   Year Built ________

4. Vessel Manufactured in Accordance with Design Specification No. ________ Date ________
   and Procedure Specification No. ________ Date ________

5. Tests on Prototype Vessel Conducted and Certified ________

6. Constructed for maximum
   allowable working pressure ________ psi at maximum temperature ________ F.
   Minimum temperature (when less than minus 20 degrees) ________ F.

   Hydrostatic / Pneumatic or / Combination } Test pressure ________ psi. Total Wt. of Completed Vessel ________ lbs.

7. SHELL: Type ________ (Bag-Molded, Centrifugally Cast, Filament-Wound) Nominal Thickness ________ in.

   Diam. ________ Ft. ________ In. Length ________ Ft. ________ In. Barcol Hardness ________

8. HEADS: Type ________ (Molded, Centrifugally Cast, Filament-Wound)

   Attachment ________ (Integral, Adhesive Bonding, Bolted, Quick Opening, etc.)

A.

	Location (Top, Bottom, Ends)	Nominal Thickness	Barcol Hardness	Nom. Weight	Shape or Contour (Describe, giving radii, angle, ratios, where appropriate)
(1)	________	________ in.	________	________	________
(2)	________	________ in.	________	________	________

B. If Bolted, Bolts used (Material, Spec. No., T. S., Size, No.)

(1) ________
(2) ________

C. If Quick Opening or Other (Describe or attach sketch)

(1) ________
(2) ________

D. If Filament-Wound, Describe Pole Pieces or Head Fittings
(1) ________
(2) ________

9. SAFETY OR SAFETY-RELIEF VALVE OUTLETS: Number ________ Size ________
   Location ________

10. NOZZLES:

Purpose (Inlet, Outlet, Drain)	Number	Diam. or Size	Type	Material	Thickness	Reinforcement Material	How Attached
________	________	________	________	________	________	________	________
________	________	________	________	________	________	________	________
________	________	________	________	________	________	________	________

11. INSPECTION OPENINGS:

Manholes, No. ________ Size ________ Location ________

Handholes, No. ________ Size ________ Location ________

Threaded, No. ________ Size ________ Location ________

12. SUPPORTS: Skirt ________ (Yes or No) Lugs ________ (Number) Legs ________ (Number) Other ________ (Describe)

Attached ________ (Where and How)

13. REMARKS: ________

(Brief description of purpose of the vessel, such as Air Tank, Water Tank, L.P.G. Storage, etc.) (Describe resin system used and any unusual features of design or construction not covered by items 3 to 12 inclusive)

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Fiberglass-Reinforced Plastic Pressure Vessels — Section X.

Date ________ 19____ Signed ________ (Manufacturer) By ________

Certificate of Authorization Expires ________

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY ________ at ________

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province ________ and employed by ________ of ________ have inspected the pressure vessel described in this manufacturer's data report on ________ 19____, and state that to the best of my knowledge and belief, the manufacturer has constructed this pressure vessel in accordance with the applicable sections of the ASME Boiler and Pressure Vessel Code.

By signing this certificate neither the Inspector nor his employer makes any warrant, expressed or implied, concerning the pressure vessel described in this manufacturer's data report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ________ 19____

________ Inspector's Signature Commissions ________ Natl. Board, State, or Province, and No.

FORM RP–2
MANUFACTURERS' PARTIAL DATA REPORT
A Part of a Fiberglass-Reinforced Plastic Pressure Vessel Fabricated by One Manufacturer for Another Manufacturer

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code

1. (a) Manufactured by ____
(Name and address of manufacturer of part)

(b) Manufactured for ____
(Name and address of manufacturer of boiler or vessel)

2. Identification – Manufacturer's Serial No. of Part ____________________
(a) Constructed According to Blueprint No. __________ B. P. Prepared by __________
(b) Description of Part Manufactured and Inspected ____________________
3. Part Manufactured in Accordance with Procedure Specification No. __________ Date __________
4. Remarks ____

We certify that the statements made in this manufacturer's partial data report are correct and that all details of materials, construction, and workmanship of this vessel conform to the ASME Code for Fiberglass-Reinforced Plastic Pressure Vessels – Section X.

Date __________ 19____ Signed __________ (Manufacturer) By __________ (Representative)

Certificate of Authorization Expires __________ 19____

CERTIFICATE OF SHOP INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province __________ and employed by __________ of __________ have inspected the part of a pressure vessel described in this manufacturer's partial data report on __________ 19____, and state that to the best of my knowledge and belief, the manufacturer has constructed this part in accordance with the applicable sections of the ASME Boiler and Pressure Vessel Code.

By signing this certificate, neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the part described in this manufacturer's partial data report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date __________ 19____

__________ Commissions __________
Inspector's Signature — Nat'l. Board, State, or Province and No.

FORM RP–2 (back)

5. SHELL: Type ______ (Bag-Molded, Centrifugally Cast, Filament-Wound) Nominal Thickness ______

Nominal Weight ______ Diameter ______ Ft. ______ In. ______

Length ______ Ft. ______ In. Barcol Hardness ______

6. HEADS: Type ______ (Molded, Centrifugally Cast, Filament-Wound)

Attachment ______ (Integral, Adhesive-Bonded, Bolted, Quick Opening, etc.)

A.

Location (Top, Bottom, Ends)	Nominal Thickness	Barcol Hardness	Nom. Weight	Shape or Contour (Describe, giving radii, angle, ratios, where appropriate)
(1) ______	______ in.	______	______	______
(2) ______	______ in.	______	______	______

B. If Bolted, Bolts used (Material, Spec. No., T. S., Size, No.)

(1) ______

(2) ______

C. If Quick Opening or Other (Describe or attach sketch)

(1) ______

(2) ______

D. If Filament-Wound, Describe Pole Pieces or Head Fittings

(1) ______

(2) ______

7. Constructed for maximum allowable working pressure ______ psi at maximum temperature ______ F.

Minimum temperature (when less than –20 degrees) ______ F.

8. SAFETY VALVE OUTLETS: Number ______ Size ______ Location ______

9. NOZZLES:

Purpose (Inlet, Outlet, Drain)	Number	Diam. or Size	Type	Material	Thickness	Reinforcement Material	How Attached
______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______

10. INSPECTION OPENINGS:

Manholes, No. ______ Size ______ Location ______

Handholes, No. ______ Size ______ Location ______

Threaded, No. ______ Size ______ Location ______

11. SUPPORTS: Skirt ______ (Yes or No) Lugs ______ (Number) Legs ______ (Number) Other ______ (Describe)

Attached ______ (Where and How)

FORM RP-3
MANUFACTURERS' TEST REPORT OF SAFETY VALVES
As Required by the Provisions of the ASME Code Rules

1. Manufactured by ______________________________
(Name and address of manufacturer)

IDENTIFICATION OF VALVE

2. Manufacturer's Type or Style No. ______________ Serial No. ______________
3. Inside Diameter of Valve Seat ______________ (In. (1000 ths))
4. Inlet Pipe Size ______ (In.) Outlet Pipe Size ______ (In.) Screwed or Flanged ______
5. Inside Spring, Outside Spring (cross out one) Flat Seat, Bevel Seat (cross out one)
6. Seat Angle ______ (Deg.) Material of Body ______ of Valve Disk ______

of Valve Seat ______ Weight of Completely Assembled Valve ______ (Lb.)

AUTHORIZATION TEST RESULTS

7. Type of Test: By Weighed Condensation, By Flowmeter (cross out one)
8. Popping pressure ______ (Lb. per sq. in. gage) Closing Pressure ______ (Lb. per sq. in gage)
9. Blowdown ______ (Lb. per sq. in.) Relieving Capacity ______ (Lb. per hr. by test)
10. Lift, at Relieving Capacity ______ (In.) Pressure during Capacity Test ______ (Lb. per sq. in. gage)

Pressure in Exhaust Pipe during Capacity Test ______ (Lb. per sq. in. gage)

11. Fluid Used in Tests ______ (If not saturated steam, indicate per cent moisture or molecular weight, M, if other fluid)
12. ASME Boiler Code Capacity (90 percent of Test Capacity) ______ (Lb. per hr.)

REMARKS

13. Place of Test ______ Date of Test ______
14. Does the Valve Chatter? ______ Does the Valve Stem Leak? ______

Was Valve Stem Leakage Measured? ______

We certify the above data to be correct and that the relieving capacity of the safety valve conforms with the ASME Code rules and that the valve conforms to the following drawings ______

Signed ______ (Manufacturer) By ______ Date ______ 19___

Signed ______ (Authorized Observer) Date ______ 19___

INDEX

1968 ASME
BOILER AND PRESSURE VESSEL CODE

WITH ADDENDA THROUGH DECEMBER 31, 1969

NOTE: Prices for individual Sections will be increased by issuance of subsequent Addenda.

I. POWER BOILERS

Rules for construction of power boilers, electric boilers, miniature boilers and high temperature water boilers to be used in stationary service. Includes those power boilers used in locomotive, portable and traction service.

$13.00 ($10.40 member price)

II. MATERIAL SPECIFICATIONS –

Part A – Ferrous *$13.50 ($10.80 member price)*
Part B – Nonferrous *$13.50 ($10.80 member price)*

Specifications for ferrous (Part A) and nonferrous (Part B) materials that have been adopted for boiler and pressure vessels built under Code rules. More extensive, revised rules reflecting increased scope of materials coverage to provide for industry requirements.

III. NUCLEAR VESSELS

Minimum requirements for materials, design, fabrication, inspection, testing and certification of vessels for use in nuclear construction power plants. Appendices include: stress analysis methods, basis for establishing design stress intensity values, non-mandatory preheat requirements, porosity charts, capacity conversions for safety valves and manufacturers' data report forms.

$15.00 ($12.00 member price)

IV. HEATING BOILERS

Rules cover minimum construction requirements for design, fabrication, installation and inspection of steam heating, hot water heating and hot water supply boilers which are directly fired with oil, gas, electricity or coal and for operation at or below pressure and temperature limits set forth in this document.

$12.00 ($9.60 member price)

VII. RECOMMENDED RULES FOR CARE OF POWER BOILERS

Purpose is to promote safety in the use of power boilers. Includes rules for: routine operation, operating and maintaining boiler appliances, inspection, prevention of direct causes of boiler failure, operating and maintaining power boiler auxiliaries, control of chemical conditions and partial rules for installation.

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CASE INTERPRETATIONS BOOKLET

The Boiler and Pressure Vessel Committee meets regularly to consider requests for interpretations of the Code and to consider rulings for conditions encountered requiring special provisions. Those which have been adopted are published in this booklet.

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BINDERS

For all sections
$6.00 ($4.80 member price)

For Case Interpretations Booklet
$5.00 ($4.00 member price)

VIII. PRESSURE VESSELS –

Division 1 *$16.50 ($13.20 member price)*

Minimum construction requirements for design, fabrication, inspection and certification of pressure vessels. In three sections: A, general requirements applicable to all pressure vessels; B, specific requirements applicable to the various methods used in fabrication of pressure vessels (welded, riveted, forged and brazed method); and C, specific requirements applicable to the class of materials used.

Division 2 *$15.50 ($12.40 member price)*

Presents an alternative to the requirements of Div. 1. Div. 2 rules are more restrictive in choice of materials allowed, but permit higher design stress-intensity values to be employed in range of temperatures over which the design stress-intensity value is controlled by the ultimate strength or the yield strength.

Guide to Alternative Rules

The companion piece to Division 2, this booklet covers the rationale of this Division. Included are a brief summary of the requirements for each of the Sections of Division 2.

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Criteria for Design by Analysis in Sections III & VIII, Division 2

Provides explanations for strength theories, stress categories and stress limits on which design procedures of these Sections are based.

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Rules applying to qualifications of welding and brazing procedures, welder and brazer, and welding and brazing operators for all types of manual, machine arc and gas welding processes permitted in other sections of the Code. Three parts include: requirements for ferrous materials, for nonferrous materials and for brazing ferrous and nonferrous materials.

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Case interpretations supplements published six times a year and the semi-annual colored sheet addenda to the Sections of the Code may be obtained on a subscription basis through June 1971, date of the new edition.

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